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CELESTIAL CHEMISTRY, AND THE PHYSICAL CONSTITUTION OF THE STARS AND NEBULÆ.

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(*With a Coloured Plate.*)

FEW things are more remarkable in the present aspect of science than the manner in which its various departments come into contact one with another, thus aiding the student in a way quite unlooked for, and throwing light upon the subject of research from a quarter whence it was least expected. As when stones are thrown into water, so the circle of each science at first seems to be totally distinct from all the others, but gradually these separate circles enlarge and widen, until they intersect and produce larger circles and wider generalizations in the increasing domain of human knowledge. Thus, chemistry was, in the time of Davy, furnished with a new and powerful analytical agent in the shape of voltaic electricity, and the same agency, which is itself evoked by chemical action, has given us the long series of discoveries in electro magnetism, culminating in the splendid practical application of the electric telegraph. So, too, photography, which is essentially chemical in its nature, has been of the greatest service to the physicist in furnishing him with a constant and unerring record of the indications of his barometer, thermometer, and magnetic instruments, and has even come to the assistance of the astronomer and depicted for him the changing appearances of the moon's surface, the spots on the sun, and the fleeting phenomena of a solar eclipse.

Quite recently the application of some of the phenomena of light to the discrimination of the chemical constitution of bodies, or *spectrum analysis* as it is called, is a discovery of the highest order and most extraordinary utility to the chemist, while its extension to the discovery of the cause of the dark lines

of the solar spectrum, and hence of the chemical nature of the atmosphere surrounding the sun's photosphere, is one of the most striking examples of that mutual assistance and interdependence of the sciences of which we were speaking. So soon as Kirchhoff saw the significance of the discovery of the reversal of the bright lines of metallic spectra by passing their light through vapour of the same matter, he wrote: "The method of spectrum analysis not only offers a mode of detecting with the greatest simplicity the presence of the smallest traces of certain elements in terrestrial matter, but it also opens out the investigation of an entirely untrodden field, stretching far beyond the limits of the earth, or even of the solar system. For, in order to examine the composition of luminous gas, we require only to see it, and it is evident that the same mode of analysis must be applicable to the atmosphere of the sun, and of the brighter fixed stars."

Brilliantly has this prediction been verified by his own researches on the sun, and by the elaborate observations of Mr. Huggins and Dr. Miller on the other heavenly bodies. Of these latter researches, we now proceed to give some account.

To the INTELLECTUAL OBSERVER for June, 1863, Mr. Huggins contributed a paper on the subject of "Spectrum Analysis applied to the Stars," to which we would refer all readers of the present article for the necessary introductory knowledge of the subject, should they not already be possessed of such elementary information. The valuable paper on "Spectroscope Apparatus," in the November number of this Journal, may also be usefully consulted. Gladly would we have left the subject to be continued by the original discoverer of the results obtained, but unfortunately Mr. Huggins cannot spare the necessary time, and therefore the present writer, with his concurrence, will endeavour to describe what has been done since the article referred to was published.

The great point of the paper of June, 1863, was to lay before the readers of the INTELLECTUAL OBSERVER an account of the observations made by Mr. Huggins and Dr. W. A. Miller upon the spectra of the Fixed Stars, including diagrams of Sirius, Aldebaran, and Betelgeux, as presented to the Royal Society in a note dated February, 1863. Some few of the lines in the diagrams there engraved had been ascertained by measurement, but the greater number were due to eye estimation; and while certain metals, such as sodium, iron, and magnesium, were almost certainly shewn to be present in certain stars, the author stated that he and Dr. Miller considered the direct observation of the coincidence of stellar lines with metallic lines so important that they intended not to rely upon measures, but to compare the metals directly with the stars.

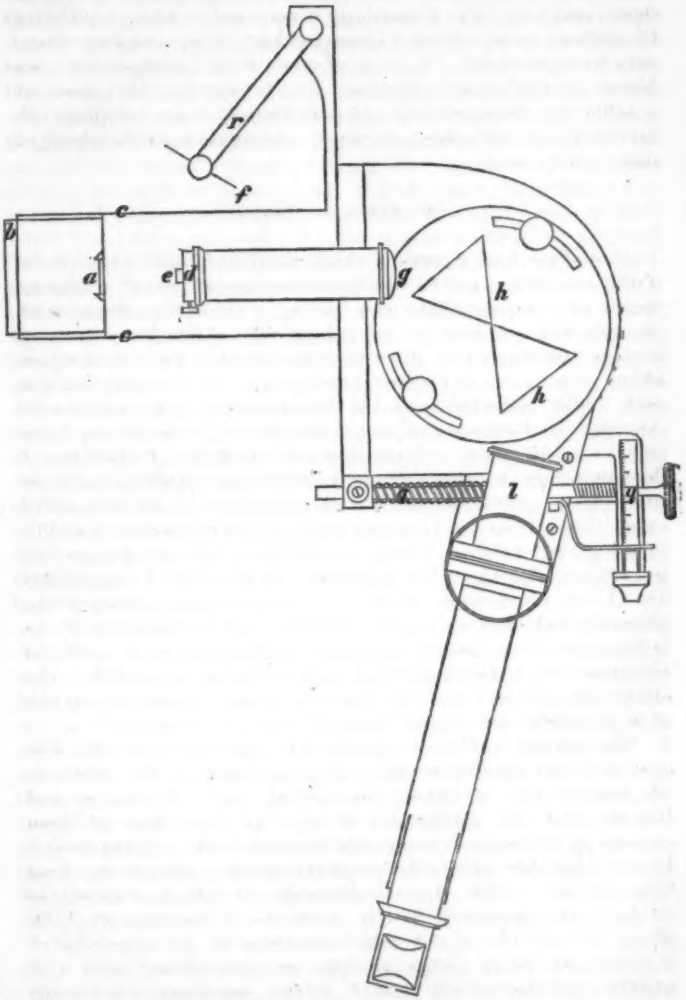
But here a difficulty arose, some of the metals had not had their spectra examined with the necessary precision, while the very minute and accurate maps given by Kirchhoff were not equally complete for all parts of the spectrum; besides, in these maps the comparisons being with the lines of the solar spectrum, they were not so available for night work. Mr. Huggins then determined on constructing his own maps of the metallic spectra, and struck out the idea of adopting the bright lines of the air spectrum, always obtained when the induction spark is taken in air, as his standard of measurement and of reference for the metallic lines. He therefore entered on a long and elaborate set of experiments, rendered more troublesome by the extreme difficulty of obtaining the chemical elements in a state of absolute purity, which made it necessary, in many cases, for him to procure the metals by electro deposition from their solutions. For the purpose of this investigation, Mr. Browning of the Minories, so famous for his spectroscopes, supplied six prisms of very dense glass, which were arranged in an apparatus, the form of which will be understood from the account of such instruments given in the November number. The metals were volatilized by being made the electrodes of a very powerful induction coil.

By means of a small prism, covering one-half the slit of the collimator, the air spectrum could, when necessary, be seen simultaneously with that of the metal under examination. For many months did Mr. Huggins carry on these difficult and delicate experiments, until, in December, 1863, he was able to communicate the results of his labours in a paper to the Royal Society. This paper contains tables of measures, and diagrams of the lines in the spectra of common air, and of twenty-four metals, including sodium, potassium, calcium, barium, strontium, manganese, tellurium, thallium, gold, tin, iron, silver, cadmium, antimony, bismuth, mercury, cobalt, lead, zinc, arsenic, chromium, platinum, osmium, and palladium.

Independent of the value of these observations for future researches on the stars, they were also productive of the discovery of new lines in some of the spectra observed, among which may be mentioned several lines in the sodium spectrum, in addition to the well known double one corresponding to D of the solar spectrum. Armed with these new materials, Mr. Huggins prepared to resume his operations on the heavens, being again assisted in the stellar observations by Dr. Miller, but making those on the nebulæ, which have resulted in the important discovery we shall presently mention, exclusively himself; and of these stellar observations we shall now present the leading features.

Before giving in detail the important results which have

been arrived at, it is necessary to offer some description of the apparatus employed. In the article on spectroscopes previously referred to, the construction of these instruments has been described, but the modifications necessary for their application to sidereal observations require notice. It is obviously necessary to concentrate the light of such faint bodies as the stars before admitting it to the prisms for dispersion, and therefore a telescope of large size became necessary to the observer. Mr. Huggins possesses, in his convenient and well-appointed observatory at Upper Tulse Hill, an instrument having an object-glass of eight inches aperture, and ten feet focal length, made by Alvan Clark, of Cambridge, United States, formerly used with much success by the Rev. W. R. Dawes. This he has had mounted equatorially by Cooke and Sons of York, and this superb instrument, accurately driven by clockwork (an essential condition), forms the condenser of the light of the faint bodies to be submitted to spectral analysis. Another peculiarity of the apparatus requires notice: as a star forms a point of light only in the focus of the object-glass, this would be drawn out by the prisms into a fine line of coloured light without sufficient breadth for observation of the fine lines crossing it. Some mode of expanding it (and in one direction only, so as to prevent unnecessary loss of light) to give the required breadth to the spectrum is needed, and a cylindrical lens, as originally employed by Frauenhofer, was found to be the best thing for this purpose. In the accompanying engraving of the apparatus used by Mr. Huggins and Dr. Miller, the cylindrical lens is marked *a*. It is plano-convex, about an inch square, and of fourteen inches focal length. It is mounted in a tube *b*, sliding within the tube *c*, by which the apparatus is attached to the eye end of the telescope. The slit for the admission of the light is marked *d*, and over one-half of it is placed the right-angled prism *e*, to receive the light for the metallic spectra of comparison. The light of the metallic sparks is sent by the mirror *f* through a hole in the tube *c* to the prism. The achromatic collimating lens is marked *g*, and the two dispersing prisms of very dense glass *h*. The spectrum is viewed through a small achromatic telescope marked *l*, having a positive eye-piece magnifying nearly six times. This telescope is carried by a micrometer screw *q*, capable of dividing the space from A to H in the solar spectrum into 1800 parts, and the telescope being furnished with a cross of wires, it is obvious the distances of the lines can be measured with extreme accuracy. The arm *r* carries the wires and forceps connected with the induction coil for deflagrating the metals whose bright lines are examined for coincidence with the dark ones of the stellar spectra. The prisms of this apparatus were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made by Mr. Ross, the cylindrical lens, and some other parts, by Mr. Browning, and the micrometer by Cooke and Sons. In later observations, two other prisms and another small telescope, made by Mr. Browning, were used, which, with less dispersive power, afforded increased brilliancy, and were occasionally very useful. The excellence of the arrangement was shewn by the sharp definition of the lines in the solar and metallic spectra, and by its permitting a line between the double D of the solar spectrum, attributed by Kirchhoff to nickel, to be seen.

THE MOON AND PLANETS.

One of the first questions which presented itself to the minds of the observers, was to test the existence or not of an atmosphere to our satellite, the moon. On all astronomical grounds, the evidence of no appreciable atmosphere is very strong; but there are other points connected with the subject which have a little contrary tendency. It is clear that the sun's light, reflected from the lunar surface, must pass twice through the thickness of any atmosphere the moon may have before reaching us, and judging by the effects of the rays of the sun, when at a low altitude, traversing a length of our own atmosphere, any lines due to its existence should be readily seen. With this view, the spectrum of the moon was carefully examined on many occasions, and while it presented a perfect accordance with the solar spectrum, the lines B, C, the sodium line D, the magnesium group b, F, G, and many others of the Frauenhofer lines being seen, nothing could be traced that was indicative of a gaseous envelope about the moon, and the evidence of spectrum analysis may therefore be added to the other reasons for believing that the moon, at any rate on the side presented to our view, has little or no atmosphere.

The planets, shining equally by light reflected from the sun, exhibit numerous phenomena indicating the existence of atmospheres, of which the varying belts of Jupiter and Saturn, and the diminution of light at the edges of these planets, and Mars and Venus, may be mentioned. The snow and ice of Mars also could only be produced by a gaseous envelope like our own. Still, at first, although the reflective character of the light was proved by the existence of the lines B, C, D, E, b, F, and G, of the solar spectrum in the spectrum of Jupiter, any fresh lines, showing an atmosphere, were not visible until the second pair of prisms, previously mentioned, was used, when the saving of light allowed a line in the red to be seen, and subsequently, by comparing the spectrum of Jupiter with that of the sky at sunset, several other differences

were found. Some bands of lines, corresponding to the lines produced by our atmosphere, were stronger in the spectrum of Jupiter than in that of the sky, while others were fainter. In the former case, it would seem that the constituents of Jupiter's atmosphere exerted an absorbing effect on the light; and in the latter, the light of the sun passing through the lower and denser part of our atmosphere was more strongly affected by it than by the atmosphere of Jupiter. The same thing, under similar circumstances, had been observed in the case of the moon. That a strong line in the red was due entirely to Jupiter's atmosphere, was shown by examining the moon and Jupiter when near together; the result being, that while the planet possessed the line, the moon did not, whereas had it arisen from our atmosphere, it must have been common to both. The comparison of the lines of Jupiter with those of our atmosphere tend strongly to the supposition that some of the gases composing the planet's atmosphere are the same as those which constitute our own. The spectrum of Saturn gave almost the same indications, but the observations were more difficult from want of light. In Mars, some lines in the extreme red were seen, and the spectrum diminished suddenly in brilliancy at F, from the occurrence of numerous bands, which absorbing the more refrangible rays, evidently cause the predominance of the red tint in the light of this planet.

With regard to Venus, although, as might be expected, the spectrum was of great beauty, and the principal solar lines well shown, D being even seen double, no specific atmospheric lines could be traced.

The analysis by the prism of the light of the planets, while it largely confirms the astronomical doctrine of their possessing extensive atmospheres, may, perhaps, be thought less conclusive than might have been expected; but, on the other hand, it should be remembered that, with the exception of Mars, telescopic observation shows that we are looking not directly at the bodies of the planets, but at masses of cloud suspended in their atmospheres, and reflecting the sun's light to us, and therefore such light has passed through but a very small and rarified portion of such atmospheres, instead of through the lower and denser portions, which we know, in the case of our own aërial covering, to be the principal source of the specific atmospheric lines.

THE FIXED STARS.

Striking as are the results obtained by spectrum analysis when applied to the sun, moon, and planets, they sink into insignificance when compared with the revelations afforded us

of the constitution of those distant bodies, the stars, and the light which is thus thrown upon their structure is conclusive as to their being of the same nature as our own sun; a result which analogy had previously indicated, but which had not been supported by any positive evidence. It might be supposed that their distance offered insuperable obstacles to such an inquiry, but spectrum analysis knows no such limits, and as long as we can obtain light of an incandescent substance from a suitable source, it matters not whether it exists within a few inches of the spectroscope, or at a distance of unnumbered millions of miles, the result being equally certain.

The difficulties of these observations from other causes are, however, very great, arising principally from the extremely few occasions when telescopic observations with a large instrument can be carried on in this country, on account of the frequent atmospheric changes. The amount of work done in the past two years, although at first it appears small in quantity, is in reality quite remarkable, and bears testimony in a high degree to the devotion and patience of the observers, as, in consequence of the few fine nights available when a star is in a good position, the mapping of a single star completely would occupy several years. The diagrams in Mr. Huggins's article of June, 1863, show the result of the cursory examination of three first-class stars, but since that time the apparatus has been improved, and a large number of fine lines have been observed in addition to those previously seen. In the spectra of all the brighter stars that have been examined, the dark lines appear to be as numerous and as fine as in the solar spectrum. The great breadth of the lines shown in the former diagram of Sirius, and which band-like appearance was so marked as to specially distinguish it from the other stars of the diagram, has to a very great extent disappeared, and though these lines are still strong, they now appear, as compared with the strongest of the solar lines, by no means so abnormally broad as to require this star, and some similar ones, to be placed in a class apart. No stars sufficiently bright to be observed are without lines, and therefore star differs from star only in the arrangement of the lines, and consequently in the elementary substances present; but all the stars are constructed on one and the same plan. The number of fixed stars observed amounts to nearly fifty, but the observations of three or four occupied most attention, and two only have been mapped with any degree of completeness. The coloured plate accompanying this article gives a representation of these two spectra, namely, of Aldebaran and of Betelgeux (*a* Orionis), with a portion of the solar spectrum for a scale of comparison.

The lines beneath the spectra indicate the position of the principal metallic bands, showing the coincidence or otherwise. The colours of the spectra are the same as those of the solar spectrum, but much fainter, Aldebaran being the stronger of the two, and many of the extreme rays at both ends are too faint for perception.

Aldebaran is of a pale-red tint, and the spectrum is full of lines in the orange, green, and blue. We shall presently see the significance of this fact. About seventy lines were measured, and these being compared with the chart of the metallic elements, a number of approximate coincidences were selected to be tested by a direct comparison of the stellar and metallic spectra. Sixteen terrestrial elements were thus made to present their characteristic bright lines above the dark ones of the star, and sodium, magnesium, hydrogen, calcium, iron, bismuth, tellurium, antimony, and mercury, answered perfectly to the test, and proved their existence in the atmosphere of Aldebaran. Seven elements, nitrogen, cobalt, tin, lead, cadmium, lithium, and barium, gave negative evidence only. Indications of other elements were not wanting, but the observations of these fine lines were too fatiguing to the eye to be pressed further.

Betelgeux (α Orionis) has a very full spectrum. The light of the star is orange, and the lines are thickest in the red, green, and blue. About eighty lines have been measured and mapped, and sixteen elementary substances tested for coincidence. With five of these, sodium, magnesium, calcium, iron, and bismuth, the connection is complete, and certain. Perhaps thallium also exists, but the line seen might be calcium, the apparatus not having dispersive power enough to separate the lines of the two metals at that particular point. In the case of hydrogen, nitrogen, gold, cadmium, silver, mercury, barium, and lithium, coincidence was not proved. By reference to the coloured plate, the coincidences will at once be seen, and the relative positions of the lines of the other elements which were compared.

β Pegasi gives a much fainter spectrum, and fewer lines have been measured; of this star a diagram is not given. Sodium and magnesium, and perhaps barium, exist in its envelope. Iron and manganese are doubtful, but nitrogen, tin, mercury, and hydrogen were not present. The absence of hydrogen from α Orionis and β Pegasi is a point of considerable importance, as its presence is eminently characteristic of the spectra of the sun and some forty fixed stars, which have been examined.

This observation is valuable, since it proves that the lines which indicate its presence belong to atmospheres of the lumi-

nous bodies themselves, and not, as might have been expected, to our own atmosphere.

Although a very bright star, the observations of Sirius are extremely difficult, from its low altitude in this country, by which it is brought within the densest and most impure part of our atmosphere. Sodium, magnesium, hydrogen, and probably iron, have been found by coincidences, and a photograph of the spectrum was obtained on wet collodion, but owing to the combined difficulties of the experiment, the lines could not be traced in the picture. It is, however, believed by the observers that further experiments will result in this important object being attained, and the facility which will then be afforded of comparison of the more refrangible and less luminous parts of the stellar spectra, when thus self-registered, with existing metallic charts, must be obvious.

Vega (α Lyræ) has a spectrum full of lines. Those of sodium, magnesium, and hydrogen have been identified. Capella certainly contains sodium. This star was photographed at the same time as Sirius. In the spectrum of Arcturus thirty lines were measured—that of sodium is present; but in this and all the other stars referred to, the work is still incomplete, although in progress. Pollux shows sodium, magnesium, and iron; α Cygni and Procyon sodium; and the following stars have been observed, and their lines partly measured, but metallic comparisons have not yet been made. Castor, ϵ, ζ, and η Ursæ Majoris; α and ϵ Pegasi; α, β, and γ Andromedæ, the last an interesting spectrum; Rigel, full of lines; η Orionis; α Trianguli; γ and ϵ Cygni; α, β, γ, ϵ, and η Cassiopeiæ; γ Geminorum; β Canis Majoris; β Canis Minoris; Spica; γ, δ, and ϵ Virginis; α Aquilæ; Cor Caroli; β Aurigæ; Regulus; β, γ, δ, ϵ, ζ, and η Leonis.

One of the most important and interesting deductions which the observers, whose work we have been discussing, draw from their results, is connected with the origin of the colours of the stars. That there is great variety of tints among these bodies is well known; white, yellow, and red stars are the most frequent, whilst in double stars the contrasted colours are often green or blue. The source of the light of the stars, as well as of that of the sun, must be a solid or liquid body in a state of incandescence, as only such bodies, when raised to a high temperature, give a continuous spectrum. In the case both of the sun and stars, this continuous spectrum becomes crossed by dark bands, which are produced by the absorbing power of the constituents held in a vaporous form in the investing atmospheres. These atmospheres vary in chemical constitution according to the elements composing the star, and should the dark lines produced by the absorptive power of the

vapours forming the stellar atmosphere, and which correspond to the bright lines they would form in an incandescent state, be strongest and most numerous in the more refrangible portions of the spectrum, then the star would have a red or orange tint, because this part of the spectrum would suffer least absorption; while, on the contrary, should the red and yellow portions have most lines, the blue and green rays would predominate in the colour of the star. The frequency of the lines in the orange, green, and blue of Aldebaran's spectrum, previously pointed out, is strongly in favour of this theory, as the red is left little affected, and the other tints are subdued by the dark lines. α Orionis has the red, green, and blue rays much diminished, which produces the orange colour of this star; and β Pegasi, which much resembles α Orionis in its spectrum, has a deep yellow hue. In Sirius, which is of a brilliant white, there are no lines sufficiently intense in any particular part of the spectrum to interfere with our receiving the light in about the same proportion, as to the quantity of the different coloured rays, to that in which it starts from the incandescent light-giving surface.

It became a matter of great interest to test this theory with respect to the double stars, which present the most marked difference in colour; but the faintness of the blue or green companions rendered the observations very difficult. Still, with the second pair of prisms, which because of their less dispersive power give a more brilliant spectrum, observations of β Cygni and α Herculis were obtained, which accord remarkably with the theory just propounded. Thus, in the bright star of β Cygni, which is light orange in colour, the blue and green rays are full of lines, while the few in the red and yellow are far apart; in the small star, on the other hand, which is deep blue, the red and orange part of the spectrum is full of groups of fine lines that interfere with those rays, and leave the blue end, which has lines few and far between, dominant in the light of the star. The colours of the components of α Herculis, which are severally reddish and green, appear to be produced in strict conformity to the same hypothesis; and although the theory cannot be considered as established by these instances, it must be regarded as exhibiting a high degree of probability, while the singular variability in the colours of stars at different times, which cannot fail to occur to our readers as not at present explained, may yet prove to be capable of some elucidation by further investigations in the same direction. Of course change in the chemical constitution of the investing atmospheres would be an obvious cause of change of colour; but these latter changes are too frequent, and recur with such unvarying regularity

at the known periods, to admit of such an operation being admitted.

The spectrum observations have also an important bearing on the nebular hypothesis of the cosmical origin of the universe, as showing that the elementary substances must have existed in different proportions at different points of the nebulous mass, otherwise by condensation equal proportions of the elements, from the surrounding vapour, would have been collected. There is here an analogy to the manner in which the components of the earth's crust are distributed. Some of the elements are widely and universally diffused throughout animal, vegetable, and mineral matter; while others, as the rarer metals, are accumulated at particular points, and whatever the reason of this separation, the benefits to the human race caused thereby are many and obvious.

The knowledge derived from these observations has induced Mr. Huggins and Dr. Miller to indulge in some speculations, which are so legitimate and so ably put forward by them in the paper of May, 1864, that we cannot do better than allow them to speak for themselves, especially as the paper itself may not fall within the range of many of our readers.

"The closely-marked connexion, in similarity of plan and mode of operation, in those parts of the universe which lie within the range of experiment, and so of our more immediate knowledge, renders it not presumptuous to attempt to apply the process of reasoning from analogy to those parts of the universe which are more distant from us.

"Upon the earth we find that the innumerable individual requirements which are connected with the present state of terrestrial activity, are not met by a plan of operation distinct for each, but are effected in connection with the special modifications of a general method, embracing a wide range of analogous phenomena. If we examine living beings, the persistence of unity of plan observable amidst the multiform varieties of special adaption of the vertebrate form of life may be cited as an example of the unity of operation referred to. In like manner, the remarkably wide range of phenomena which are shown to be reciprocally inter-dependent and correlative of each other, by the recent great extension of our knowledge in reference to the relation of the different varieties of force, and their connection with molecular motion, exhibits a similar unity of operation amidst the changes of the bodies which have not life.

"The observations recorded in this paper seem to afford some proof that a similar unity of operation extends through the universe as far as light enables us to have cognizance of material objects. For we may infer that the stars, while dif-

fering, the one from the other, in the kinds of matter of which they consist, are all constructed upon the same plan as our sun, and are composed of matter identical, at least in part, with the materials of our system.

"The differences which exist between the stars are of the *lower order* of differences of *particular adaptation*, or special modification, and not differences of the *higher order* of distinct *plans of structure*.

"There is, therefore, a probability that these stars, which are analogous to our sun in structure, fulfil an analogous purpose, and are, like our sun, surrounded by planets, which they by their attraction uphold, and by their radiation illuminate and energize. And if matter identical with that upon the earth exists in the stars, the same matter would also probably be present in the planets genetically connected with them, as is the case in our solar system.

"It is remarkable that the elements most widely diffused through the host of stars are some of those most closely connected with the constitution of the living organisms of our globe, including hydrogen, sodium, magnesium, and iron. Of oxygen and nitrogen we could scarcely hope to have any decisive indications, since these bodies have spectra of different orders.* These forms of elementary matter, when influenced by heat, light, and chemical force, all of which we have certain knowledge, are radiated from the stars, afford some of the most important conditions which we know to be indispensable to the existence of living organisms, such as those with which we are acquainted. On the whole, we believe that the foregoing spectrum observations on the stars contribute something towards an experimental basis, on which a conclusion, hitherto but a pure speculation, may rest, viz., that at least the brighter stars are, like our sun, upholding and energizing centres of systems of worlds adapted to be the abode of living beings."

THE NEBULÆ.

By far the most wonderful of the revelations of spectrum analysis applied to the heavenly bodies has yet to come. Encouraged by his success with the fixed stars, Mr. Huggins resolved to apply this new and potent method of research to the examination of those mysterious bodies, the Nebulæ, and this investigation was rewarded by one of the most important discoveries connected with the physical constitution of those wonderful objects, and with the cosmical origin of the universe, which we venture to think has ever been made. From the time of Sir W. Herschel, who took up Messier's scanty list of

* That is, differ entirely at different temperatures and pressures.

103 Nebulæ, and increased them to 2500, throwing out at the same time the supposition that although he had resolved nearly all those of Messier's list into clusters of stars, and discovered hundreds of other clusters, yet that there were numerous nebulæ which, from their being easily visible, and yet resisting every attempt by increased aperture or power to resolve them, must really consist, not of stars or separate masses of condensed solid matter, but of gaseous or vaporous fluid. He was thence led to those beautiful speculations which, enlarged and illustrated by Laplace, who showed the mathematical possibility of such an action of condensation as Sir W. Herschel required, have become widely known as the *Nebular hypothesis*, and as to the validity of which so much controversy has been excited. We all know, too, that of late years the tendency of telescopic observation, as conducted by the magnificent instruments of Lord Rosse, and corroborated by the splendid achromatic of Harvard University, Cambridge, U. S., has been to reduce the numbers of the irresolvable nebulæ; and in particular that, after the great nebula of Orion had, in parts at least, been resolved, the general impression was that the nebular hypothesis had lost all substantial evidence in its favour, and though it still might be contended that the existing systems had such an origin, yet that examples of matter in the nebulous form were not to be found in the heavens. Still, it must not be forgotten that Lord Rosse, while resolving many of the nebulæ, had discovered others which resisted his instrumental powers, and that to many clusters there were fantastic wisps of nebulous light appended, and diffuse patches of light attached, which defied resolution, though they were evidently connected with the objects he pronounced to be starry in construction.

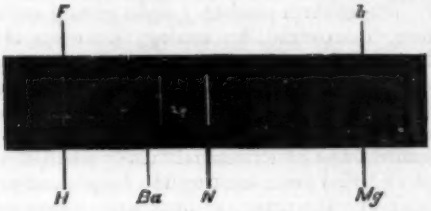
Amongst the most wonderful of the nebulous bodies are those called by Sir W. Herschel *planetary nebulæ*. These present the appearance of small discs of uniform light, usually circular, and generally blue, or bluish green in colour. They are few in number and bright, looking, in the telescope with a low power, very much like stars out of focus. Now it was apparent to Sir W. Herschel that bodies like these, having no central condensation of light nor stellar nucleus, could not be globular clusters of stars, which necessarily would be brighter in the centre than at the edges. A cylinder form of stars seen endways might certainly present such an appearance, or a flat disc of stars placed at right angles to our line of sight would also look like a planetary nebula; but such forms are too improbable to detain us a moment. He, therefore, came to the conclusion that these were masses of truly nebulous or vapoury matter in the primal form, and presenting various

stages of the process of condensation, a few points of light being visible in some where a little solid or liquid had probably formed. This supposition, with the addition that, at some distance from the surface the matter was sufficiently condensed to prevent light from behind penetrating it, was then complete as a cause of the uniform planetary light giving surface.

Lord Rosse discovered an analogy between the annular nebulæ and the planetary forms, increasing the number of the former from two to seven, and showing that a nebula with a hollow centre, imperfectly seen in telescopes of less aperture, might present the appearance of a planetary nebula; but the question remained one of extreme difficulty when Mr. Huggins, in the autumn of this year, took up the subject, and attempted to bring analysis by the prism to bear upon these remarkable bodies, which seemed a class, *sui generis*, and of an order entirely different to the sun and fixed stars.

He was now working alone, and in September, 1864, communicated to the Royal Society results of so important a character that they have been at once printed as a supplement to the paper of May last. The apparatus was the same that we have described, Mr. Browning's excellent prisms being used; the cylindrical lens was generally removed, since the nebulæ present a visible disc instead of a point when in focus. The first object attacked was 37 H. IV. Draconis, which is described by Sir J. Herschel in his latest catalogue as "very bright; pretty small; with a very small nucleus." Its colour is greenish blue. Looked at with the telescope and spectrum apparatus, Mr. Huggins was astonished to find no spectrum visible, but only one short line of light in the direction which the dark lines always occupy in the spectrum. At first he suspected derangement of the apparatus, but this being found in good order, it became apparent that this celestial body differed from all others that had been examined, not in degree, but absolutely in kind; for its light was not composed of rays of different refrangibilities, but mostly of one monochromatic light only. Careful examination with a narrower slit detected a more refrangible, but much fainter bright line, and at about three times the distance another still fainter was seen. The direct comparison of these lines with those of the air spectrum was then made, and it was found that the brightest line corresponded with the strongest line due to nitrogen, and the faintest with one of the hydrogen lines, while the intermediate one was nearly, but not quite, coincident with a barium line. The appearance of this most remarkable result is given in the woodcut, at least as far as such an illustration will represent the different intensities. An excessively faint spectrum was also detected on both sides of the bright lines, which is, doubt-

less, due to the minute solid or liquid nucleus, and, perhaps, is crossed by dark lines. The engraving could not possibly represent this spectrum of sufficient faintness, and it is, therefore, not attempted.



The significance of this discovery is invaluable. *Terrestrial* physics show us that only liquid and solid bodies give a continuous spectrum, while gases alone, when rendered luminous by heat, give out light which, after dispersion by the prism, is found to consist of certain degrees of refrangibility only, which appear as bright lines on a dark ground. Here there was clear and unimpeachable evidence, according to the present state of our knowledge, that large masses of gas exist; and these may be the nebulous matter of Herschel and Laplace, which then is no fiction, and that we may yet fairly speculate on the process of the origin of worlds from such a primal form.

But other nebulæ were to be tested. A very similar planetary nebula, Σ 6, in Taurus Poniatowski, when examined, gave precisely the same bright lines, with the merest suspicion of a faint spectrum. 73 H. IV. Cygni gave the same three bright lines, with a stronger continuous spectrum than the nebula in Draco, extending from about D to G of the solar spectrum. This nebula has a distinct 11th magnitude star in the middle, which evidently produces the continuous spectrum, and this opinion was confirmed by a most crucial experiment. The cylindrical lens being removed from the apparatus, it was found that the three bright lines still remained of considerable length, corresponding to the diameter of the telescopic image of the nebula, while the faint spectrum became a narrow line, showing that the object producing it was a point in the focus of the object-glass. 51 H. IV. Sagittarii is a fainter planetary nebula, and the two brighter lines were seen, and the third by glimpses. 1 H. IV. Aquarii had the three bright lines sharp and distinct, but the indications of the faint spectrum were mere suspicions. Though brighter than the last, this nebula probably contains very little matter in the liquid or solid form.

57 M. Lyræ, the well-known ring nebula, was a most interesting object. Its light is very pale, and the brightest of the three lines was the only one distinctly seen, the others being, perhaps, glimpsed, but no faint continuous spectrum whatever could be detected. The bright line was remarkable, consisting of two bright spots corresponding to sections of the ring, with a very faint connecting line. Lord Rosse had previously seen much more nebulosity in the centre of the ring than had been drawn by other observers; and the spectrum shows that it is full of rare nebulous matter. Another planetary nebula, 18 H. IV., but which under a power of 600 is distinctly annular, gave a fourth excessively faint line, more refrangible than the one agreeing with F. The last object which has been examined was the celebrated Dumb-Bell Nebula, 27 M. Vulpeculæ. The light of this body after prismatic analysis remained concentrated in the strong bright line corresponding to that of nitrogen, no others being visible, nor was there any trace of a faint continuous spectrum. Various portions of this large nebula were tried, but the light, although different in intensity, was always the same in refrangibility.

So much for the positive evidence of the different constitution of these nebulæ to anything like stars, or clusters of stars; and this testimony is corroborated by the negative evidence obtained in the examination of a number of other bodies which are palpably of the class of clusters. For example, 92 M. Herculis, and 26 IV. Eridani, both fine clusters, gave continuous spectra as the stars do. 50 H. IV. Herculis though nebulous in the telescope, still produces a starry spectrum, showing its true character. 55 Andromedæ, which Herschel describes as a star with a nebulous atmosphere, gave a star spectrum, but no bright lines; and Lord Rosse notes that he has looked at it eight times and seen no such atmosphere, so that it is probably not a nebulous star at all. The examination of the great nebula in Andromeda is of much interest. The brightest part gave a continuous spectrum from about D to F, the light ceasing abruptly in the orange, and the companion 32 M. gave a similar spectrum. It would appear, therefore, that these are really clusters at the enormous and almost inconceivable distances which must be necessary so to blend the light of their constituent stars. It is, however, also possible that they may be gaseous matter so full of condensed and opaque portions as to give a continuous spectrum.

Mr. Huggins remarks, "It is obvious that the nebulæ, 37 H. IV., 6 Σ., 73 H. IV., 51 H. IV., 1 H. IV., 57 M., 18 H. IV., and 27 M., can no longer be regarded as aggregations of suns after the order to which our own sun and the fixed stars

belong. We have in these objects to do no longer with a special modification only of our own type of suns, but find ourselves in the presence of objects possessing a distinct and peculiar plan of structure."

"In place of an incandescent solid or liquid body transmitting light of all refrangibilities through an atmosphere which intercepts by absorption a certain number of them, such as our sun appears to be, we must probably regard these objects, or at least their photo-surfaces, as enormous masses of luminous gas or vapour. For it is alone from matter in the gaseous state that light, consisting of certain definite refrangibilities only, as is the case with the light of these nebulæ, is known to be emitted."*

We think our readers cannot fail to endorse this conclusion, and no one who has studied the subject and comprehends the extreme beauty of the adaptations of spectroscopic apparatus which are employed; the delicacy and care with which the observations were made, and the caution displayed in drawing conclusions only when the evidence is irrefragable, but must regard the discovery of such an analysis of the true nature of these wonderful bodies as one of the noblest additions to our knowledge which has recently been made. The speculations to which the proved existence of bodies of such enormous size, and consisting apparently of only three or four elementary substances, will give rise, are, doubtless, numerous and various in the extreme. It is singular that only one out of several nitrogen lines is seen, but Mr. Huggins has sometimes observed a difference in sharpness between this and some other bright nitrogen lines, which suggests differences in the atoms radiating the light. Again, we find the stars containing numerous elementary bodies, *can it* be possible that in the process of condensation and cooling from the enormously high temperature which the nebulæ must possess, that transmutation of the so-called elements may take place? Modern chemistry says "No!" but there are occasional indications that some of the so-called elementary bodies may yet be decomposed, or proved to be different forms of others. Time which has done so much will yet bring fresh wonders to light, and the powers of spectrum analysis will be yet further exerted in the elucidation of the problems of nature. Enough for the present, that the well-matured speculations of Herschel, and the mathematical theory of Laplace, have been vindicated from the doubt under which they have been

* Mr. Huggins has just discovered that the great nebula of Orion gives a spectrum indicative of gaseity. This instance, added to those of the Ring and Dumb-Bell Nebulæ, shows that resolution into points of light can no longer be accepted as a proof of a nebula being a cluster of stars.

labouring, and the early nebulous condition of cosmical matter, so necessary for almost all geological reasoning, proved to demonstration by the labours of our excellent observer, whose results we have detailed in this article.

ON THE FORMATION OF BOTTOM ICE IN SALT AND FRESH WATER.

Translated from the Swedish of E. Edlund,

BY "AN OLD BUSHMAN."

As is well known to all, fresh water has its greatest solidity and, consequently, its greatest weight, at a temperature of 4° Cent.,* and it is principally on this account that fresh-water lakes, with still water, freeze up at the approach of winter. When the upper layer of water on the surface of such a lake becomes chilled on account of its contact with the cold air, it sinks to the bottom, and water of a higher degree of temperature rises from the depths of the lake, and takes its place on the surface. This becomes chilled in its turn, sinks down, and leaves a place for a new layer of water, which rises from the bottom, and so on. After the whole mass of water has in this manner become chilled to a temperature of 4° Cent., this circulation ceases, and the cooling process goes on in another form. When the surface water has attained a temperature lower than 4° Cent., it remains on the surface, because it is then lighter than the water which lies below it. On this account the uppermost layer of water can be at freezing-point, and become ice, whilst the temperature of that below it is considerably above freezing point.

If we follow the old opinion, that the formation of ice can only take place on the free surface of the water, bottom ice must be regarded only as a fable. This phenomenon, however, like many others in the science of natural history, shows the folly of denying the existence of any fact in nature which we are unable to explain by any received theory; for it is now plainly shown that the formation of bottom ice is a certainty which cannot be denied.

This bottom ice in general consists of a loose, spongy matter, in appearance somewhat resembling wet, half-thawed snow, and generally assuming the shape of round plates, of different sizes and thickness. It often forms around stones, etc., which lie on the bottom. When the first ice formation takes place,

* In the Centigrade scale 4° corresponds with 39·2 Fahrenheit's scale.

the ice mass appears quickly to increase in size, and when its body becomes considerable, it rises to the surface of the water, often bringing up with it stones and other objects, which plainly proves that it has been formed on the bottom. Sometimes, however, the ice remains fast on the bottom, and gradually grows to a large mass till it reaches the top surface of the water. As far as we at present know, this bottom ice forms only in the beginning of winter—never in the depths of winter or in the spring, when the surface of the water is covered with a tolerably thick coating of ice.

This phenomenon has often been observed in Sweden, as well as in other lands. The blocking up of the streams at Motalla and Norkopping is not uncommon, and it has been observed that this mass of bottom ice consists of innumerable small oblong plates piled one above the other. In many of the streams which run through the iron districts of Wermeland this bottom ice, or, as it is called here, "krafis," often forms in the beginning of winter, and dams up the whole stream; but it is occasionally hindered by stones and other inequalities being cleared from the bed of the river, so that the water can flow in a smooth, unbroken current.

Water which is at a temperature below the freezing point is brought to freezing through shaking, but this only takes place where the particles which lie close together receive an uneven motion, so that their relative momentum is disturbed. If it happens during the shaking that the relative position of the particles to each other is not disturbed, no freezing takes place. This has been proved by experiment with a glass cylinder; and moreover, a globe of glass, which is filled with water below freezing point, can be shaken to any degree without the water freezing into ice; consequently, the upper layer of a mass of water in a river can be at a temperature under freezing point; yet, on account of its even motion, it will not become ice, and can even rush down a waterfall to the very bottom of the river, without any very great portion of it becoming frozen together. On the bottom of the river, however, this continual even motion is hindered by upright objects, which cause a whirling motion, and which, through their contact with the water, promote its congealment into ice. In order, in some measure, to hinder the formation of bottom ice, which is often very pernicious, the bed of the stream should be continually cleaned, and all inequalities removed.

We can hardly, however, consider that this phenomenon is even sufficiently understood or properly studied, so that any new observations respecting the formation of bottom ice will be welcomed; and those which follow on the formation of ice in the Cattegat are very interesting, as proving a fact which is

little known, that the ice formation in this sea scarcely ever takes place in the same manner as in inland lakes, but generally through round lumps of ice which rise up from the deeps, and freeze together on the surface. To Professor Nilsson are we indebted for the following remarks :—

ON THE FORMATION OF ICE OFF KEELLEN POINT, ON THE SOUTH COAST OF SWEDEN.

In the salt sea, ice is very seldom formed on the surface of the water (the sea is generally too rough and agitated by wind and currents), but usually in the following manner:—Small thin and flat plates of ice, of different form and size, float up often in large quantities to the surface, where, crushed and broken into small pieces, either through the dashing of the waves or the strength of the currents, they are ground against each other till the particles become small, and at length freeze together to round or flattish lumps of ice, of different sizes, which, as soon as the water becomes tolerably still, cohere, and form a compact rough covering of ice. Only close to the shore, in shallow water of four or six feet deep, and in calm weather, is salt water ice formed, as in still inland lakes, on the surface, by what is called "glanskis."

These plates of ice are very variable in form and size, but always as thick in the circumference as in the medium point. They have a diameter of from one to five inches, but a thickness of never more than two lines. Their form is generally round, but sometimes, especially in the smaller pieces, which have probably been crushed and broken, irregular and angular.

It is not known at what depth these plates of ice are formed. They are seen first when they come up to the surface, glistening and dancing in the smooth water in the wake of the boat. In clear and still weather they can be seen at the depth of two feet at least, rising up to the surface in pieces of different sizes, in incredible quantities. But we do not fancy that the above-named ice formation takes place at a very great depth. We often see, in a sharp frost, stones and branches of sea-weed covered with ice like the hoar-frost on trees, and the nearer it is to the surface of the water the broader and larger is the covering of ice, which, however, does not extend lower down than about four feet from the water's edge. But fishermen say that it can freeze at even a greater depth, even to eight feet; for twenty years since, on a very cold night, a vessel filled with live cod-fish was sunk in at least seven feet of water, and in the morning the fish were found frozen to death, and, moreover, that they have seen stones and sea-weed covered with a coating of ice even at a

greater depth. However this may be, it is pretty certain that the frost cannot penetrate, or ice masses form, at a greater depth than eight feet in the sea. On the fishing lines no ice is formed at a greater depth than four feet, and this ice is not branchy, because the line is kept in even motion, but smooth and tapering like an icicle.

The plates of ice do not come up flat, but suddenly shoot up edgewise, often with such force that they rise three or four inches above the surface of the water, and often several are piled one above the other. They are often broken in pieces by their own weight, and it is only with the greatest care that they can be taken up whole. Their colour is bluish like common ice. The stronger the frost is, the larger and more numerous are these plates of ice. If it happens that one of these ice plates lies by itself, and the weather is very still and cold, its circumference quickly increases, and in a few hours it may reach a size of two feet or more in diameter. A similar ice formation, below the water, takes place throughout the whole Cattegat, and we see such plates of ice floating all over the sea, between Keellen and Jutland, at the same time, and in the same manner. When the fishermen observe them they directly make for land, for they often come in such quantities they would soon encircle the boats and block up the passage.

We will now, for shortness, ask the following questions, and answer them thus:—

In what manner does the freezing begin?

Principally through small plates of ice which come up from below, and after that freeze together.

What is the size and colour of these plates?

The size varies from one to about five inches in diameter, and not one two lines in thickness. The stronger the frost is, the larger are these plates. The colour is the same as common ice.

Do they gradually become lighter and freeze together into a covering of ice?

These ice plates become packed by the wind and stream, and at first freeze into round lumps of different sizes, which afterwards freeze together into a covering of fast ice.

Is there any resemblance between these lumps of ice before they are frozen together and a mass of dead sea blubber (*Medusæ*), which we often see driven up into a bay on the coast after a storm in the summer.

When these plates of ice first come up, they bear no resemblance to sea-blubber; they are then too flat and thin; but afterwards, when they become worked and frozen together into circular lumps, they very much resemble floating lumps of Medusæ.

According to Chydenius, the above described process of ice formation is common, and known to all the fishermen off the coast of the islands of Aland, in the Baltic. The sounds and the bays between these islands often freeze in this manner, according to their accounts, *i. e.*, by round plates of ice coming up from the bottom in large quantities, and freezing together on the surface.

This surface freezing often takes place in so short a time that a boat which is not well out to sea, in water altogether free from ice, can hardly come into harbour before the surface of the sea is covered with ice. Martin compares the appearance of the sea ice in Spitzbergen with the bottom ice in the German rivers. According to Scoresby, the first formation of ice in the Polar Seas is in the shape of crystals, which resemble snow-flakes dropped into water at freezing-point. These crystals then freeze together into small pieces of ice of about two inches in diameter; these again freeze together into large cakes of ice, which become round by coming into collision with each other through the working of the waves. Sailors give these round cakes of ice the name of "pancakes." The ice formation in the Polar Seas takes place often in an incredibly short time. Chydenius, who accompanied the Swedish Spitzbergen Expedition in 1857, has related, that on one occasion the sea, which was quite clear of ice, in the space of a single half hour was so covered over the whole surface with ice that they could with difficulty force the boat through it. The temperature of the air during the day had not been lower than — 4° Cent.,* and no wind or stream had driven these masses of ice together, but they were formed where they first appeared.

The formation of ice cakes during the freezing of sea water is no rare phenomenon, but, on the contrary, seems to be the usual manner in which the sea freezes up. As has been before stated, the sea water becomes chilled, and the first ice formation takes place at some distance below the water's edge, or even at the very bottom, and the small round plates of ice which are the characteristics of such a formation grow together in their passage up through the cold water to the surface, and thereby attain the size of which they are generally seen. It is impossible in any other manner to explain how the sea can often become so quickly frozen over. As we have before shown, when the temperature of the air is 4° Cent., the whole surface of the sea can be frozen over in the short space of half an hour; if, on the contrary, the temperature of the water is below freezing point, the freezing, after it has once begun, goes on with the same haste, just as when we

* —4° Cent. corresponds with 24·8 Fahr.

cast a piece of ice into a glass vessel filled with water below freezing point. This phenomenon in the sea is, therefore, according to our ideas, analogous with the formation of bottom ice in rivers. In them the cold water must be carried by the stream under the free surface of the water. But this is not required in the sea, and the difference between salt and fresh water lies in this, namely, that salt water has its maximum of weight or solidity below and not above freezing point. The salt water upon which Despretz made his experiment froze to ice, when it was shaken, at —2° 55 Cent., but its greatest maximum of weight was at 3° 67. But the freezing point, as well as the maximum of weight, depends naturally on the saltness of the water. In a mixture of sea water brought from Trieste, Genoa, and Heligoland, Neumann found that the freezing point was —2° 6, and the maximum of weight at —4° 74 Cent. The cooling of sea water down to freezing point takes place in the same manner as the cooling of fresh water to 4° of cold. The colder water, in consequence of its being heavier than that which is warmer, sinks down to the bottom. The sea can, therefore, freeze without the water being agitated, and this can take place at a considerable depth below the surface. But the depth, of course, depends on the intensity of the cold. That the sea water, when it is at a temperature below the freezing point, can sink to a considerable depth has without doubt a great influence on many of the phenomena which are closely connected with its freezing. And it is in a great measure owing to this that the icebergs which float about the Polar Seas keep themselves in a vertical position of often 1500 feet high. In the water of fresh lakes, which is always coldest on the surface, a piece of ice which reached some feet under the water, could only increase in size through the freezing of the water on the water line, and, consequently, could only increase in circumference, but not in thickness. In the sea, however, on the contrary, we see often blocks of ice with the coldest water below them, and they therefore increase in size on account of a superficial freezing which takes place in a vertical position.

The reasons why both fresh and salt water should attain a degree of temperature below the common freezing point, without congealing into a solid form, are of the greatest weight in accounting for the above-mentioned phenomena, and should be deeply studied. Above all, the observations by our thermometers on the actual degree of warmth in the water are of great consequence. But these observations must be conducted with the greatest care. If a thermometer in the usual manner is lowered into the water which is below freezing point, an ice formation will soon encircle it, which raises it to freezing point, and we cannot, therefore, by this means declare what

was the temperature of the water before this ice formation took place.

In December, 1720, the Falls of Trolhattan were stopped for nine days by bottom ice, and a serious flood was the result. The rivers in Norrland often freeze up, through several masses of bottom ice rising up from the depths to the surface of the water, and then freezing together into one solid body of ice. When these masses of ice rise from the bottom they often bring up with them the largest sunken trees, and even stones of a considerable size, and break through the coat of ice which had been formed on the surface. This has several times also been observed on the Rhine. Dumatrel remarked, that when the surface of the Seine was covered with ice, the bottom of that river was also covered with a compact body of ice about thirteen lines thick. In the river Aar a good deal of ice has often been seen to come up from the bottom, where it had doubtless been formed. This ice consisted of round flat pieces, which rose to the surface of the water with the flat side in a vertical direction, often three feet above the water, when it sank to the surface and laid in an horizontal position. On one occasion several islands of bottom ice formed in the river, of which the largest had a diameter of more than a hundred feet. These islands, in the shape of cones, were fastened to the bottom by a gelatinous formation of ice. In the harbour of Pillau, an iron chain, thirty-six feet long, was lost in eighteen feet of water. Several years after the same chain was observed floating on the surface of the water, encrusted in a very thick mass of bottom ice.

Several hypotheses have been advanced to account for the formation of this bottom ice. One circumstance we must bear in mind is this, that bottom ice never forms in still fresh water, but only in such water as is, or has been, in motion just before the ice formation takes place. This observation is necessary, to give a clear idea of the phenomenon. In a mass of water which is mixed, on account of its motion the several layers of water, of different temperatures, cannot arrange themselves according to their original specific weight; but the temperature of the water at the bottom may be the same as of that on the surface. The experiments of Professor Wilcke, in 1769, respecting ice formations in fresh water, which had been cooled below freezing point, elucidated this. Professor Wilcke found, amongst other things, that if cold water at freezing point is poured into a colder glass, or if cold quicksilver is stirred up in it, or cold shot poured into it, a quantity of little ice figures rise up in the water, which appear as if they were the commencement of the formation of a mass of ice. These figures consist of little circular thin flat clear plates of

ice. These little plates of ice, at times, come up in such abundance, that when they rise to the surface they resemble smoke, and often increase during their passage up to a diameter of more than one line. When the water has reached a half or a whole degree below freezing point, Wilcke observed these same little plates of ice rise to the surface, but they were now encircled by a leafy edge. If water below freezing point which is kept in a glass cylinder, is agitated or shaken hastily, ice began to grow up from the bottom, but not in the upper water where the agitation was greatest. If water below freezing point happens to come in contact with a fast body an ice formation in general takes place, and very quickly if this fast body is encrusted with ice.

THE THICK COAL OF SOUTH STAFFORDSHIRE.

BY J. JONES, SEC. DUDLEY GEOLOGICAL SOCIETY.

THE coal-field of South Staffordshire and East Worcestershire is, in many respects, of a peculiar character; but it is particularly remarkable in the extent of its mineral treasures. The several seams of coal and clay ironstone of superior quality occur, for the most part, at a short depth below the surface, and hence the general plan of mining procedure is to work only a very limited area by means of each pair of shafts put down. The consequence of this is that the whole of the older and richer portion of the district is studded with coal-pits, either now in operation, or marking the places where the precious minerals have been exhausted. Each mine is surrounded by a vast accumulation of rubbish, which has been drawn up chiefly when getting out the particular seam known as the thick or ten-yard coal. The method of working the coal and ironstone in this district is considered by the most competent judges to be exceedingly rude, and wasteful in a high degree; but it is in the ten-yard seam above mentioned that the greatest recklessness has prevailed, and, indeed, according to recent discussions on this subject, appears to prevail at the present time. This immense deposit of fuel is so remarkable in many particulars that it claims the especial attention of geologists; but just lately, owing to an unfortunate dispute between the colliers and their masters, a very interesting mass of thick coal has been exposed in what is termed an open working. The full dimensions of the seam have been well displayed in a large, trench-like quarry, in a portion of the district where the coal measures crop out to

day-light round a dome-shaped mass of Silurian (Wenlock) limestone.

To understand the nature of this out-crop, it must be stated that the South Staffordshire coal-measures repose immediately upon the Silurian beds, no Old Red Sandstone or Mountain Limestone intervening, from which it is inferred that the area under notice was dry land during the deposition of the absent members of the geological series. When the coal was in course of formation it would seem the underlying Silurian rocks had, to some extent, assumed their present position; but, towards the close of the Carboniferous era, the igneous action, which had in this locality been a disturbing element from the commencement, became more intense, and in one place especially it found a ready vent through which the mass of molten material, forming the Rowley ridge of hills, was ejected. It is probable that, at this period, the three existing dome-shaped bosses of Silurian rocks, extending northwards in the line of the Rowley Hills, were elevated very considerably above their former level, throwing out the coal-measures which at that time more or less completely covered them. Thus it is that we now find the thick coal and other seams almost horizontal at a short distance from the Silurian eminences; but all round the flanks of these hills the coal is highly inclined, and at its out-crop is only overlaid by about ten feet of superficial deposits, consisting of drift-sand and clay, containing water-worn fossils from the adjacent Limestone beds.

The thick coal, in its line of out-crop, has been nearly all extracted; and as the quality of the fuel is not so good as at greater depths below the surface, where it has not been "weathered," faint hopes were entertained that geologists would again be able to feast their eyes on an open-air section of this, the most stupendous seam of coal which the country possesses. Owing to the circumstance before mentioned, however, the thick coal open workings have been cleared, and large quantities of what coal remained have been dug out. The position of this seam is towards the top of the series of principal deposits occurring in this coal-field. The workable coal-measures in the typical part of the district consist of:—

1. Brooch coal,	about	4 feet.
2. Thick coal	„	30 „
3. Heathen coal	„	4 „
4. New Mine coal	„	8 „
5. Fire-clay coal	„	7 „
6. Bottom coal	„	12 „

The total thickness of the deposits below the thick coal is about 350 feet, containing upwards of 30 feet of valuable coal, while

above the ten-yard seam only six to eight feet of coal is found, and of this not more than one-half is workable. The ten-yard coal has not, however, one uniform structure throughout. It is, on the contrary, divided by partings of varying thickness into from ten to fifteen distinct seams, each of which is so well defined that a thick-coal collier will readily determine from what part of the deposit any stray specimen of the coal has been obtained. In the section recently exposed near to Dudley the following divisions could be easily traced. The lowest portion consisted of about three feet of *benches* coal, which is usually cut away in the process of working. Above this was a few inches of black indurated clay, or "batt." Eleven feet of coal uninterruptedly succeeded; but this contained the *bottom slipper*, *sawyer*, and *stone* coals, each one very marked in its physical character. A layer of stone came next, and upon that nearly four feet of *slips* coal, so called from its brittle and uncertain nature, and the number of accidents which arise from this peculiarity. Succeeding this were *foot* coal, *brassils* (a rough and impure layer, containing a considerable amount of iron pyrites), *tow* coal, *white* coal (a name of doubtful origin), *top-slipper*, and *roof* coal, representing a total thickness of between 18 and 19 feet, with partings of various kinds, occupying nearly two feet. The aggregate thickness of the coal at this place is considerably in excess of its average dimensions, as the coal alone is above 36 feet from top to bottom. It must not be inferred, however, that the different members forming the ten-yard coal are always found in such close proximity, separated by such insignificant partings. The upper portions of the seam are frequently divided from the underlying measures by from 10 to 130 feet of rocky material, and form what is termed the "Flying Reed." Moreover, as the coal-measures are traced northwards, towards the newly-opened part of the field, near Cannock Chase, it is found that the seams are much thinner and more numerous than in the central and southern portions of the district. It is now generally admitted that many of these thin measures are, in all probability, the representatives of the several divisions of the thick coal, only separated by shale and sand, owing to peculiar conditions which prevailed in this part of the area when the coal was originally deposited. It would be out of place to enter here upon any examination of the theories which have been advanced in order to account for the formation of coal; but certainly the vast thickness of this, the principal seam in the South Staffordshire field, presents no small difficulties when we endeavour to explain its aggregation by any of the usual suppositions. That the conditions under which the various portions were formed differed very greatly must be

inferred from the character of the several members of the series; but the main difficulty presents itself in the small amount of foreign material which, over an area of many square miles, separates the distinct beds of coal, which collectively compose the ten-yard seam.

As before mentioned, the general method of working this valuable deposit is considered one of the most wasteful which could be adopted. Though there are two acknowledged plans of getting the thick coal, only one is practically followed, the other being confined to the estates of a few of the most intelligent proprietors. The common course is to get as much of the entire seam as can be extracted with anything like safety to the roof, which is left supported by gigantic pillars, the spaces from which the coal is cleared being called "stalls." The first stage in the process is to make the necessary galleries into the coal. These are termed "gate roads." Out of these the stalls are opened. The "holers" undermine a face of coal, after which it is brought down in as large masses as possible, and it is these falls which are so productive of accident to the miners. The ventilation is carried on by means of air-ways running parallel to the gate roads, and communicating with the "sides of work;" and though this plan is very imperfect, the seam is not generally charged with much fire-damp (or "sulphur," as it is locally defined), so that accidents from explosions are not frequent in thick coal workings. After the whole area has been gone over in the manner above described, the pillars are taken down in a second operation; and if the ordinary method of mining is dangerous, this is much more hazardous. After this process of getting the "ribs and pillars" is completed, the overlying materials, and of course the surface of the ground, rapidly sink, causing buildings to crack and fall to pieces, while not unfrequently, when a pillar is removed, the superincumbent mass falls, making a yawning chasm like a crater. These "crownings in" are very common when the coal does not lie at any great depth. The other and safer method of getting the coal is by what is termed the "long wall" system. The upper measures are first worked out completely, and the ground is allowed to "settle." Afterwards the remainder of the coal is extracted in a similar manner. The gate roads are first driven to the boundary, after which the beds are worked in long "sides," back towards the shafts, and the roof is allowed to fall in as the mining processes proceed.

It has been stated, on the authority of a gentleman well acquainted with the working of the thick coal, that the actual amount of material in this seam may be put down at 48,000 tons per square acre; but of this only about 24,000 tons can

be satisfactorily accounted for as being brought to the surface. If this is really a true representation of the case, one-half of this, the thickest, and one of the most valuable of our coal-beds, is being lost for useful application by the wasteful method of working at present generally adopted. It is only just to state, however, that several of the viewers affirm that the loss in mining is much less than above assumed; in fact, according to some calculations, we are asked to believe that as much coal is obtained as can be reasonably expected. Pending the further discussion of this matter, perhaps it would be premature to offer any decided opinion on the reliance to be placed on either of the statements above referred to; but it is the general impression that the prevailing system of working the ten-yard coal is a wasteful process, and that a large proportion of the mineral wealth of this coal-field has been irretrievably lost, and hence that it is rapidly approaching a period when its busy manufactures must in great part cease. There can be little doubt that this vast iron-producing district, over which, in thriving times, a dense canopy of smoke continually hangs, and reflects at night the lurid glare from thousands of furnace, forge, and colliery fires, has reached, if it has not already passed, the meridian of its prosperity. The countless tons of valuable fuel which have, in former times, been lost for all purposes of productive industry, will naturally hasten the decline of those manufactures which depend mainly upon the abundant and cheap supply of coal; and hence it appears a matter for deep regret that no legislative supervision has yet been put upon the methods of working our mineral wealth. The teachings of science are daily set at nought through the greater part of the "Black Country," not only in the processes by which the coal is extracted, but in the various branches of the iron-trade—the staple industry of the district. There is no organization with respect to the drainage of the mines. Every proprietor does what he best can, or thinks best, to rid himself of the water which collects in his mine; but in the majority of cases the same water is allowed to find its way into adjoining mines, and thus has to be again raised to the surface. The winding and other appliances connected with the pits are nearly all of the rudest possible description. The primitive horse-gin is in operation in many places. The shafts have generally no guides, and safety-cages are exceedingly rare. The mine agents are, as a rule, not well acquainted with the principles of geology or of mining science; but there are indications that considerable improvement is taking place among this important body of men. In no district of the country is there more crying need for some comprehensive diffusion of scientific truths, for, though much of its wealth is already lost, there yet remains no

inconsiderable part of the thick coal untouched, while the secondary measures have to be worked over a very large area. Moreover, recent scientific research tends to the conclusion that the thick coal may be reached by penetrating the red (Permian) rocks which have generally been regarded as cutting off the beds of coal. If these prospects are only realized, and if more scientific methods are introduced into the mining and manufacturing industries of this important locality, the decadence of its prosperity, which now seems ominously near, may be indefinitely postponed. It is to be hoped that the approaching visit of the British Association to the district will have some influence in promoting the application of scientific principles to the practical work of this busy centre, and that thus it may be still further proved that science is the handmaid of manufacturing enterprise.

NOTES ON SOME OF THE SMALLER RODENTS FOUND IN NORTH-WEST AMERICA.

BY J. K. LORD, F.Z.S.,

Late Naturalist to the British North American Boundary Commission.

High up on the snow-clad summits, and in the deep dark solitary ravines of the Cascade and Rocky Mountains, dwell several curious and interesting animals belonging to the order Rodentia.

Having spent ten years of my life wandering, trapping, hunting, and collecting specimens of natural history in the wildest solitudes of North-West America, few if any have had more time and opportunity to watch the habits of these tiny hermits.

How often it happens that we get an isolated specimen of some curious animal or bird, and only infer what its habits are by investigating its anatomical structure. It would be difficult, perhaps impossible, to find a group of animals to which this applies with greater force than to the smaller Rodents. Hence it is that I am induced to add my mite to the treasury of science.

There is a strange, indescribable, mysterious delight in discovery, seeing animals for the first time at home in their native haunts, that before one had vaguely heard or only read of—finding a new species—digging as it were from nature's exhaustless mine, from realms unknown, fresh wonders of Divine handiwork eye had not gazed on before. I shall never

forget the exquisite pleasure I experienced when first I saw the little animal, the subject of my present notes. It was a diminutive Rodent, of the genus *Lagomys*, and, as its name implies (*lagos*, a hare, *mus*, a mouse), being a sort of intermediate link between the hares proper and the guinea-pigs.

All the known species of the genus are entirely confined to the northern parts of the world; four species are all that have hitherto been described. One, the Pika, or Sadajack, from Siberia; one from Mongolian Tartary; a third from the north-eastern part of Russia; the fourth from the Rocky Mountains.

The general appearance of the Pikas is more suggestive of a guinea-pig (*Cavia*) than a hare. The (*Cavia Australis*) common in the mountain regions of Uspallata, is named the mountain rabbit, from its close external resemblance to that animal. But there are important and well-defined structural differences between Lagomys and the hares—the skull in the Pika is more depressed and broader behind; the supra-orbital process is wanting; the orbits are differently shaped, and the malar bone reaches nearly to the auditory opening; instead of the cribriform arrangement in the nasal process of the superior max bone, as in hares and rabbits, there is in Lagomys but one large opening. In Lagomys the vomer joins the anterior sphenoid; but in hares, these bones are separated by an oblong opening. The upper incisors are broad, each tooth having a vertical groove on the outer side; the lower incisors are much smaller than the upper. The molars are much the same as in hares, with transverse ridges of enamel. There are other slight differences, but not of sufficient importance to need mention here.

Of their habits nothing hitherto seems to have been known, and as I have only to introduce the two species found on the Cascade and Rocky Mountains—one, a new species, discovered by myself, and named (*Lagomys minimus*, Lord), the other, previously described by Sir John Richardson—I shall relate the story of my finding them.

In the summer of 1858 I set out on a collecting and hunting expedition from Fort Colville, one of the early trading posts of the Hudson's Bay Company, situated in a beautiful valley on the upper part of the Columbia river, my object to ascend the Cascade range of mountains. My route to follow up the Na-hoil-a-pitqua river, and then to strike across the Osoyoos lakes, and keep along the banks of the great Shimilkameen river, to strike Ashtnolow, a tributary that led up into the mountains, the course of which I was to follow as far as practicable. I had a delightful trip through a district indescribably lovely.

There is a wild and massive grandeur about the eastern side of the Cascades, unlike the scenery on the west, or coast slope, which is densely wooded. Here it was like riding through a succession of parks, covered with waving grass and countless flowers of varied species. Shutting in the valleys, like Titan walls, rose vast piles of plutonic, metamorphic, and trappean rocks, records of the eruptive elevatory forces that had tilted up Mounts Baker and Rainer into the regions of ice and everlasting snow.

I reached the junction of the two streams, and camped just as the sun was disappearing behind the western hills. The lingering rays of the purple twilight seemed loth to leave, and clung faintly to the ragged peaks of the rocks, that shut me in on every side; not a sound of bird or beast awoke the solemn silence of the forest, and, save the babble of the stream, as it rippled over the shingle, all nature seemed hushed in deathlike sleep. I could dimly make out in the fading light the grim hill I had to climb at dawn, it towered up, like a mighty giant, high above all its brethren, the clear white snow covering its summit sharply defined, and contrasting strangely with the black sombre pine trees, standing like sentinels guarding the lower portion of the mountains.

By the time I had started my fire it was pitch dark; nothing disturbed my night's repose, save the howling of a pack of skulking wolves, that I had to scatter with a fire stick.

The "world's great eye," as it came peeping over the hills, roused me from my sound sleep, and warned me it was time to be up and stirring. I had a stiff climb before me, and my hopes were high in expectation of bowling over some big-horn (*Ovis montana*) and ptarmagan. For some distance I scrambled up the side of the brawling mountain torrent, whose course, like true love, was none of the smoothest, being over and among vast fragments of rock that everywhere covered the hillside. Struggling out from these relics of destruction grew the great Douglas pine (*Abies Douglasii*), the graceful Menzies pine, and ponderous cedar (*Thuja gigantea*); here the ascent was easy enough, but, as I reached a greater altitude, the climbing was anything but a joke.

The *Pinus contorta* and *Pinus flexilis* were now the only trees, and a few Alpine flowers peeped out here and there from among the granite *débris*. I reached a level plateau near the summit, much fagged, and lay down on the soft mossy grass near a stream, that came trickling down from the melting snow.

In every direction, as far as eye could scan, there were nothing but hills of all shapes and heights, whilst far below,

in all the haze of mist and distance, I could see the valley I had left.

Close to my couch was a talus of broken granite, that old time and the frost king between them had crumbled away from a mass of rocks—so immense, that no hand, save that of He who made them, could have lifted them on one another. As in awe and wonder I contemplated these stupendous proofs of God's power, a cry like a plaintive whistle suddenly attracted my attention. It evidently came from amongst the stones. I listened and kept quiet. Again and again came the whistle; but nowhere could I see the whistler. A slight movement at length betrayed him, and I could clearly make out a little animal sitting bolt upright, like a begging dog, his throne a flat stone in the middle of the heap.

I had a load of small shot in one barrel of my gun, intended for ptarmagan, and forgetting, in my anxiety to obtain the unknown stranger, that I should alarm the big-horn I was so bent on procuring, raising my gun slowly and cautiously to my shoulder, I fired as I lay on the ground. The sharp ringing crack as I touched the trigger—the first, perhaps, that had ever awoke the echoes of the mountain—was the death-knell of the poor little whistler.

I picked him up, and imagine my intense delight when for the first time in my life I held *Lagomys minimus* in my hand. Having discovered what he was by a most careful examination, the next thing was to watch for others—to find out what they did, and how they passed their time in their stony citadel. I had not long to wait; others soon came peeping slily out of their hiding-places, and, inferring safety from silence, sat upon the stones and cheerily whistled to each other. The least noise, and the whistle was sounded sharper and more shrill—the danger signal—when one and all took headers into their holes among the stones. I soon observed they were busy at work, carrying in bits of dry grass, fir fronds, roots and moss, and constructing a nest in the clefts between the stones, clearly for winter sleeping quarters. The nests were of large size, some of them consisting of as much material as would fill a a good sized basket. I feel sure that one nest was the combined work of several of these little labourers, and destined for their joint habitation.

There were no provisions stored away, neither do I think they garner any for winter use, but simply hybernate in the warm nest, which of course is thickly covered with snow during the intense cold of these northern latitudes, thus more effectually preventing the radiation and waste of animal heat. Their food consists entirely of grass, which they nibble much after the fashion of our common rabbit. They never burrow or dig

holes in the ground, but pass their lives among the loose stones. Who can fail to observe the evidence of Divine care and forethought displayed in clothing this tiny defenceless creature in a garb exactly resembling the grey lichen-covered fragments amongst which he is destined to pass his life? So closely does he approximate in appearance to an angular piece of rock when he sits up, that unless he moves it is almost impossible to see him, and the cry or whistle is so deceptive that I often imagined it far distant when the animal was close to me.

The species described and figured by Sir John Richardson, F.B.A., plate 19, *Lepus* (Lagomys) *princeps*, I first saw at Chilakweyuk Lake, and next on the trail leading from Fort Hope on the Fraser River to Fort Colville on the Columbia. They were in a narrow gorge among loose stones. This was about the same date as on the year preceding I had seen *Lagomys minimus* making its nest; but here not a trace of nest could I see, nor any evidence of an attempt to make one. I soon after returned again by the same trail, the snow having now fallen to the depth of about six inches, completely covering up the rocks and stones, all the little animals had disappeared; and although I searched most carefully, there was not a hole or track in the snow to show they had ever left their quarters. It was quite impossible a nest could have been made in the interim; hence I feel perfectly sure they hybernate without a nest; whereas *Lagomys minimus*, living at a much greater altitude, makes a nest to sleep through the winter in.

Lagomys minimus (Lord), *sp. nov.*

Sp. char. differs from *Lepus* (Lagomys) *princeps* of Sir J. Richardson, F.B.A., 1 p. 227, plate 19, in being much smaller. Predominant colour of back dark grey, tinged faintly with umber-yellow, more vivid about the shoulders, gradually shading off from the sides to dirty white; feet white, washed over with yellowish-brown; ears large, black inside, the outer rounded margin edged with white; eye very small and intensely black; whiskers long and composed of about an equal number of black and white hairs; no visible tail. Measurement, head and body, 6½ inches; head, 2 inches; nose to auditory opening, 1¼ inch; height of ear from behind, 1 inch.

The skull differs in being generally smaller, the nasal bones are broader and shorter and rounded at their posterior articulation, instead of being deeply notched as in *Lagomys princeps*, distance from anterior molars to incisors much less.

I scarcely know a more beautiful illustration of adaptation than that of fitting these two species to their destined localities, implanting instincts amounting almost to reason. The one, living on the cold barren summit of the mountain, makes a warm nest to pass away the winter in, warmth being an

equivalent for food; the heat-supplying materials are economized, and, like a lamp slowly burning, life goes on during the period of hybernation.

The other, tenanting the sheltered valleys, where the snow never remains long and food is readily obtained, simply digs or burrows under a stone, and feeling no necessity, cares not to build himself a house.

In the same range of mountains lives that rare and singular little animal the *Aplodontia leporina*, of which I shall have something to say in my next.

THE GREAT WATER-BEETLE (*DYTICUS MARGINALIS.*)

BY REV. W. HOUGHTON, M.A., F.L.S.

(*With a Tinted Plate.*)

EVERY searcher of ponds and ditches for animals wherewith to stock his aquarium is, doubtless, familiar with the large water-beetle (*Dyticus marginalis*), of active habits and predaceous disposition. In the present paper I purpose to say a few words about this king amongst Aquatic Coleoptera. I will first of all draw attention to his habits and form, and then offer a few remarks on the examination of some parts of his internal organization, with especial reference to the digestive apparatus. The great water-beetle is a capital subject for insect dissection. Its large size renders the task of an anatomical investigation, comparatively speaking, simple and easy. It is, moreover, widely distributed throughout this country, and readily procurable at most seasons of the year: in the winter, however, it buries itself in the mud, and is difficult to meet with. I have searched in vain a couple of hours a-day for specimens of Dyticus, during the winter, in ditches where the summer previously I could obtain any number.

The great water-beetle is, both in its larval and imago state, one of the most voracious insects in existence. If kept in an aquarium, his predaceous disposition soon manifests itself. Woe betide the unfortunate stickleback or newt that is once caught and held by the strong mandibles of this fresh-water tyrant. It little matters what is the size of the victim attacked. I have seen Dyticus rush upon a full-grown smooth newt, and no twistings and writhings of his eftship was of any avail. Burmeister has recorded of a kindred genus (*Cybister Röselii*), that it devoured in the short space of forty hours two frogs, and that so rapid was the digestive process,

THE GREAT WATER BEETLE.

1. Digestive apparatus of Dytiscus marginalis.
2. Spiracle of ditto, magnified.

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1. Digestive apparatus of Dytcus marginalis.
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that he was unable to find any remains in the intestinal canal, upon his dissecting the beetle shortly afterwards. The voracious habits of the larva of Dyticus are as great as they are in the perfect insect; but owing to the greater strength of the mandibles, and more fully developed muscular system of the beetle, the insect is a more formidable enemy to the other inhabitants of the water than the larva.* The Dyticidæ, however, though naturally very voracious, are able to live some weeks without food. The male is recognized by his smooth elytra; the female has furrowed elytra and a rough thorax. The male, moreover, is readily distinguished by the form of his fore feet, the two anterior tarsi of which are expanded into a circular cavity on the under side, covered with a number of suckers. The wing covers in both sexes are provided internally with a pair of small membranes nearly circular, and ciliated at the margins, which some writers suppose are instrumental in producing the humming sounds which they occasionally make. The wings are large and at their anterior parts transversely folded beneath the elytra. These insects have been observed to leave the water, and take to flight. I never myself witnessed a specimen in the act of flying. In the warm months the water-beetle may be seen swimming in a pond or ditch, every now and then rising to the surface, and protruding the tail portion of the body, so as to admit the air through the opening elytra to the spiracles. These extremely beautiful structures (see Fig. 2) are eighteen in number, and are in connection with a system of tracheal tubes, which ramify in all directions through the whole system, forming the respiratory apparatus. The surface of the back underneath the wings is clothed with glossy brown hairs, which by the repulsion of the water enables the admitted air to gain free access to the spiracles. The last pair of legs are fringed with long hairs, forming an oar-like apparatus, by means of which the beetle is enabled to move about with great swiftness in the water. It is a very interesting sight to see the ease and rapidity with which a large water-beetle rows himself out of harm's reach when disturbed as he lies at the surface of the water. Well has Prof. Rymer Jones remarked, "Nothing is, perhaps, better calculated to excite the admiration of the student of animated nature than the amazing results obtained by the slightest deviation from a common type of organization; and in examining the changes required in order to metamorphose an organ which we have already seen performing such a variety of offices, into fins adapted to an

* Mr. Frank Buckland has lately drawn attention to the sad havoc these water-beetles cause amongst young salmon, as witnessed by himself in a pond at Hollymount Farm, Galway. See "The Field," of Nov. 26.

aquatic life, this circumstance must strike the mind of the most heedless observer. The limbs used in swimming exhibit the same parts, the same number of joints, and almost the same shape as those employed for creeping, climbing, leaping, and numerous other purposes; yet how different is the function assigned to them. In a common water-beetle, the *Dyticus marginalis*, the two anterior pairs of legs, that could be of small service as instruments of propulsion, are so small as to appear quite disproportionate to the size of the insect, while the hinder pair are of great size and strength; the last-mentioned limbs are, moreover, removed as far as possible by the development of the hinder section of the thorax, in order to approximate their origins to the centre of the body, and the individual segments composing them are broad and compressed, so as to present an extended surface to the water, which is still further enlarged by the presence of flat spines appended to the end of the tibia, as well as of a broad fringe of stiff hairs inserted all round the tarsus. The powerful oars thus formed can open until they form right angles with the axis of the body, and from the strength of their stroke are well adapted to the piratical habits of their possessors, who wage successful war, not only with other aquatic insects and worms, but even with small fishes, the co-inhabitants of the ponds wherein they live."

The eggs, which are cylindrical in form, are deposited at different times in the summer and autumn. Like the eggs of the Ephemera, they are dropped in packets into the water, and left to take care of themselves. It is said that the larva is hatched in about the course of a fortnight, and that it casts its skin when four or five days old, at which time it is about five lines long. As the growth of the larva proceeds, the skin, which, as in the Crustacea, becomes too tight for the body, is repeatedly cast, and it is very common to see these cast-off exuviæ floating amongst the duckweed and confervæ of ponds. A full-grown larva is about two inches in length, and is said to attain its full size in about fifteen days. It then quits the water, and forms itself a round cavity in the adjacent bank, changing in about a week's time to a pupa. (See Figure.) In this state it continues for two or three weeks, and then changes to the perfect insect, which at first is soft and yellowish, but gradually hardens, and acquires its proper consistency in about the space of eight days.

Let us now take a view of some parts of the internal structure of the beetle, and more particularly the intestinal canal, or digestive apparatus. We will place this specimen (which we know from the furrows on the elytra to be a female) in a small gutta-percha trough, with the back uppermost, fastening

the head to the bottom of the trough by means of a strong pin. Now we will fill the trough with water, and our subject is ready for dissection. Let us first of all remove the elytra, taking notice of the circular membranes at their bases, as before alluded to; we then unfold the wings, and with the scissors nip them off at their juncture with the thorax, disclosing the abdomen with its beautiful covering of glossy brown hair. We can now count the spiracles on each margin of the body, which we may observe are placed rather high, so as the more readily to admit the air that fills the cavity formed by the enveloping elytra or wing cases. A magnified figure of a spiracle is shown in the engraving. We will next insert the point of the scissors at the tail extremity, and cut upwards, in a line with the axis of the body, as far as the thorax, then make a tranverse cut on each side, and turn the membrane back, holding it with the forceps. What a magnificent spectacle to be sure! Look at those threads which run up the inner surface of the membrane, bright as silver. See how innumerable are these delicate fibres which run in all directions. These we recognize as the *tracheæ*, or respiratory apparatus of the insect; and we cannot take a single portion of the beetle and submit it to a microscopic examination without seeing some of these beautiful silvery fibres. Let us cut away these abdominal segments so as to expose the internal parts to view. We observe between the skin and intestine a thick network of fatty matter investing every organ, bound together by the delicate tracheæ. We will remove as much as we can of this adipose matter, and try to discover the intestinal canal. What is this body covered with numerous little villosities? It is the stomach, which we will seize gently with the forceps, and then trace downwards to the anus, taking care not to break the delicate structure. Having freed this portion of the tube, we will proceed upwards to the head and mouth; cutting through the thorax and using much care lest we sever the membrane.

We have succeeded, let us suppose, in dissecting out the entire intestinal canal. We must now float it out in another trough, or suspend it by a thread in a test-tube and examine it. First, then, we notice at its upper extremity an expanded portion—this is the *pharynx*, the distended commencement of the *œsophagus*, which latter portion of the tube reaches to a small bulbous-like organ, in form resembling the cup of an acorn (see Fig. 1). The part of the tube just above this bulbous body is seen to expand into a sack-shaped crop (*ingluvies*). In this crop the food is first prepared. If a Dyticus be opened soon after a meal, the ingluvies will be seen to be distended with the food. From the crop the nutritive

matter passes into the bulbous body (the *proventriculus*) where it undergoes trituration by means of a series of horny spines or teeth, eight in number, readily recognized by its yellow colour. The *proventriculus* which is very muscular, evidently corresponds to the gizzard in birds. From the *proventriculus* the food descends to the stomach or *ventriculus;* herein, from the presence of a number of investing secreting organs, it is evident that the food is more fully prepared for assimilation. If we open the *proventriculus* by a finely-pointed pair of scissors, and examine a portion of its internal surface, we shall see that these glands communicate with it, and doubtless pour into it a secreted fluid. To the stomach succeeds the *duodenum*, into which two pairs of anastomosing filaments of a chocolate colour run. Then follows the *ilium* and the *colon*, the distinction between which, however, are not always very apparent.* The complicated lines of a brown colour, which twist around a large part of the whole intestinal tract, are usually called the biliary vessels. In insects, to quote the words of Milne Edwards, "there exists no liver, properly speaking, but this organ is replaced by long and delicate tubes which float in the interior of the abdomen and open superiorly into the chyle-forming stomach. These biliary vessels also take the place of urinary glands, for it is here that the uric acid is formed." These vessels are supposed by some writers to correspond rather to the kidneys of the higher animals than to their liver. "If we consider these organs as kidneys," Van der Hoeven observes, "it becomes uncertain whether insects have a liver; for the idea that these vessels may represent at once both kidneys and liver (whence it has been proposed to name them *vasa urino-biliaria*), is not, as appears to me, the result of comparative investigation, either anatomical or physiological, and would never have been entertained but for the attempt to reconcile two conflicting views, and which ought always to be distrusted when it interferes with more extended inquiry."

Van der Hoeven gives some reasons for believing that the encircling fatty matter may represent the liver of higher animals. "Since the production of fat," he adds, "exerts the same influence on the composition of the fluids as the separation of bile, it is not to be considered as a proceeding entirely arbitrary, if some recognize in the adipose body an analogon of the liver." There does not, however, seem to be any reasonable doubt that the term "biliary" is correctly ascribed to these organs, and that *they* represent the liver of

* Careful focussing with ¼ inch objective reveals the presence of three distinct membranes throughout the entire length of the intestinal tract, but their nature and form will not be understood without drawings.

higher animals. The true urinary organs, at least in Dyticus are probably represented by the vessels usually denominated "anal." They are double, each consisting of a delicate tortuous tube—the kidneys—which leads to a bladder from which proceed an excretory duct. The colour of these organs is generally of a bright sulphur in those specimens I have examined. They are situated near the *anus*, on each side of which they appear to pour out their contents.

How, it may be asked, are the nutritious products of digestion assimilated by insects which do not possess any lacteal system, as occurs in the Vertebrata, nor veins, which in the Mollusca absorb the nutritive materials? The chyle is supposed to pass through the walls of the intestine and to become mixed with the blood in the cavity of the body. "This transudation has, indeed, been actually witnessed," we are told, "by Ramdohr and Rengger, and even analysed by the last-mentioned physiologist, who found it to consist almost entirely of albumen."

The examination of the anatomy of insects is attended with very great pleasure to the student of Natural History, but, at the same time, it must be confessed that much difficulty besets his investigations, and there is need of a large stock of patience and perseverance. The best thing to do is to select several large species of the different orders, and begin upon them; it is advisable, also, to make one part of their organization the object of more especial study. The *Dyticus marginalis* might be taken as a type of the internal structure of the *Coleoptera;* a dragon fly (*Libellula* or *Œschna*) of the *Neuroptera;* a cockroach of the *Orthoptera;* a sphinx moth of the *Lepidoptera;* a humble bee of the *Hymenoptera*. By this means a general knowledge will be obtained which may be improved by a more extended examination of different species of the same orders. Burmeister's Manual, and old Swammerdam's Book of Nature, together with Newport's valuable paper on Insects in Todd's Cyclopædia, with Rymer Jones' General Outline of the Animal Kingdom, will be found useful to the physiological entomologist.

The figure which illustrates the digestive apparatus, it should be stated, represents the intestinal tract in a straightened form. The whole portion from the stomach to the anus in its natural position in the insect is considerably twisted. The pendent portion on the right side of the stomach is part of the *adipose matter;* not a salivary gland, for which it might be mistaken.

AIDS TO MICROSCOPIC INQUIRY.

IV.—Notes on Organic Chemistry.

Living organisms are composed either entirely of soft substances, or of soft substances strengthened and supported by harder materials. A growing tree exhibits fluids which are concerned in supplying new materials, soft tissues in which growth is going on, and hard tissues in which growth has been completed. A living animal may be entirely soft, like one of the Gregarina, spoken of in the last number, in the article on Zoological Classification; or it may contain hard parts, giving support to the soft, as in the sponges, whose spicula are either calcareous or siliceous; or, as in a man, whose firm bones owe their strength and density to phosphate of lime, interpenetrating an organic material. The soft parts may, in the aggregate, be described as the *substantive* portions of the creature, while the hard parts perform the function of *adjectives*, qualifying —by supporting and strengthening—the soft parts in particular directions, or as a whole. The soft parts of organisms are mainly composed of four substances, oxygen, hydrogen, nitrogen, and carbon. Of these, the first three are *gases;* that is to say, when separated from their compounds they exist in the aeriform state under any known conditions of temperature, pressure, etc. The fourth is a solid, which, in its pure state, has neither been melted nor volatilized.

Most of our readers will be acquainted with the leading properties of these four substances; but as we intend this series of papers to help beginners, as well as to suggest some useful reflections to those who are more advanced, we shall say a few words about each one, by way of introduction. Oxygen is a widely present substance, and is essential to life, as we know it, on our globe. It constitutes eight-ninths by weight of pure water, which is a definite compound, and about twenty-three hundredths by weight of ordinary air, which is a mechanical, and slightly varying mixture, of oxygen, nitrogen, together with minute quantities of all sorts of things capable of existing in the gaseous state, and which assume that condition through the natural operations that take place on the globe. Of a given volume of air, oxygen constitutes about one-fifth, the remaining four-fifths being nearly all nitrogen, as the other substances, ammonia, etc., found in air, only exist in minute proportion. Oxygen is a very active body. Its name announces it as an "acid-maker," which it is abundantly, though not exclusively, as was once thought. It is what is called a great "supporter of combustion," though not the only one; and *ordinary* cases of burning, whether fast as in a fire, or slow as in respi-

ration, and certain kinds of decay, take place as results of oxygen combining with the thing or things said to be *burnt*. Oxygen is rather heavier than common air, its specific gravity being 1·1056. In addition to its largely entering into the composition of water and air, it constitutes at least one-third of the known constituents of the solid globe.

Hydrogen is the lightest known substance; a given quantity only weighs one-sixteenth as much as the same quantity of oxygen. In contact with or mixed with oxygen it is capable of burning, and the product is *water*, of which it constitutes one-ninth by weight.

Nitrogen is remarkable for its negative qualities when isolated, and for the active properties of many of its compounds. When mingled with oxygen to form air, it reduces the force with which its more active companion operates upon organic and inorganic substances. It will neither burn nor allow what are called combustibles to burn in it. Like hydrogen, it is not adapted to respiration. Although it does not burn in oxygen, as hydrogen does, it combines with that gas under appropriate conditions, and in various proportions. One of these compounds, nitric acid, is a substance that acts with destructive energy upon organic bodies.

Carbon, in a pure crystalline state, presents itself as the diamond, while various forms of charcoal, graphite, etc., exhibit the same substance in an amorphous condition, and with more or less impurity. In some states, carbon readily burns in an atmosphere of oxygen, or common air, so soon as it is brought to a red heat. In other conditions it is very difficult to burn at all. The result of its direct combination with oxygen, through combustion, is carbonic acid—the gas that effervesces in soda water and ginger beer.

Oxygen, hydrogen, nitrogen, and carbon all stand on the list of the chemist's "elementary substances;" that is to say, they have hitherto resisted all efforts to decompose them.

They all exist in the mineral world, in plants and in animals. In the first, they form compounds with each other, or with other substances, the general characteristics of which is *simplicity;* in the second and third, they form other compounds, the general character of which is *complexity*.

Those who have not mastered the elements of chemistry may understand this paper, if, in addition to the facts already cited, they will for a moment consider the character of chemical composition. If we make a mixture by rubbing up two bodies, such as chalk and charcoal, our microscopes would show little unchanged particles of each, lying side by side. If we mix oxygen and nitrogen so that the compound contains 21 parts of the former, and 79 parts of the latter, we shall have manu-

factured atmospheric air. In this compound the two constituents will behave just as might be expected from mere dilution. The oxygen does not, in any way, alter its properties, but they are reduced in energy by the admixture of nitrogen. No microscope can exhibit the molecules of either gas, so that we cannot tell, by that mode of examination, that a molecule of oxygen and another of nitrogen lie in juxtaposition, as we found the particles of charcoal and of chalk. We can, however, devise experiments which lead to the conclusion that atmospheric air is only such a mixture; and as oxygen is heavier than nitrogen, it would separate and fall to the bottom if gases did not possess a property of interdiffusion; so that, if we have two bottles, one above the other, connected with a long narrow tube, and fill the lower bottle with oxygen, and the higher one with nitrogen, they will, in opposition to gravity, mix very thoroughly together. In a chemical combination, the elements are so combined as to form a new substance, which usually differs from both constituents. Thus two dry gases, oxygen and hydrogen, form water, which bears no resemblance to one or the other. Chemical compounds differ from mechanical mixtures in being of a definite character—exactly eight parts by weight of oxygen and one of hydrogen form water, and it cannot be made with either more or less. If the hydrogen be taken from the water, and carbon substituted, we may obtain an oxide of carbon, instead of an oxide of hydrogen; but in the new compound, six parts by weight of carbon will exactly replace the one part by weight of hydrogen, and neither more nor less will do, though two parts of the oxygen will combine with one part of the carbon, and form a more highly oxygenated compound. The general law is that bodies combine in definite proportions, which bear to each other a certain relation of weight; and if they combine in more than one proportion, the higher compounds will contain some simple multiple of the weight found in the lowest compound. Thus, if oxygen and hydrogen are found in a thousand compounds, they will stand related to each other in such compounds by weight, either as 8 is to 1, or any simple number of times 8 is to any simple number of times 1.

The simplest sort of chemical compound is when a single atom or equivalent of one substance is combined with a single atom of another substance. A more complicated compound may consist of single equivalents of two bodies, each composed of two separate substances; and we may ascend in the scale of complexity until we reach substances containing a great many atoms of several elementary bodies, all united to form a chemical whole. In the mineral world we find a comparative simplicity of composition, often accompanied by great *stability*;

so that a mineral body may frequently be exposed to considerable heat, or to the action of powerful substances without suffering change. We have such a material in glass, which is softened, but not changed, by being made red hot, and which, when shaped into a bottle, will contain powerful acids that would speedily destroy wood, or dissolve ordinary metals. In the organic world, we not only find highly complicated substances, but generally such as possess little stability, which are easily decomposed, or changed, by heat or by chemical re-agents. Bodies in this condition of *mobility* are essential to the process of organic life, just as other bodies remarkable for *stability* are essential to the construction of the strong framework of the globe. Vitality is only exhibited (in connection with organism) so long as active chemical and other changes occur; and processes of growth differ from processes of decay, in the rate at which they progress, and in the accommodation of their speed to that of other processes going on in the same creatures at the same time.

In contemplating a living organism, we observe growth by accession of particles taken in from without, and modified according to the special requirements of the case. But in each organism portions of that which is taken in will be discarded as *waste*, and portions of the matter forming the creature will become effete, and be discharged by a machinery more or less complex, according to the rank of the organism.

Formerly it was supposed that the mode in which oxygen, hydrogen, nitrogen, carbon, etc., were built up in living organisms, differed entirely from anything that could be accomplished by purely chemical and physical means. "Life" was conceived to be a mysterious *principle*, changing, according to its own wants, the character and action of physical and chemical forces. Men of great authority thought so while chemistry was either occupied with *analysis* (the taking of compounds to pieces), or with building up new compounds, so simple as to present no resemblance to those produced by living beings. Now, chemistry has not only entered upon the path of *synthesis*, or composition, but it has made such great advances therein as to justify the belief that all the chemical compounds found in the organic world have had their origin purely and simply under the action and guidance of chemical laws.

No organic life has yet been proved to exist, except as a consequence of previous life, standing towards it in a more or less obvious parental relation. Science has done nothing—perhaps never can do anything—in the way of showing how life *began*; but having certain living beings before us, we can trace their offspring from their first germs to their completest forms. We do not know why or how life is connected with

organization; but whenever the organization with which it is connected either builds up, or takes to pieces, a chemical compound, we have good reason for believing that it does so in a manner analogous to that which a chemist can employ. Already the chemist can make a great many of the peculiar substances found in living beings; but if he could make them all, he would not therefore be able to produce living beings. He would simply have imitated certain processes which such beings perform, and as in the legend of Prometheus, the fire from heaven would still be wanted to complete his work. The mystery of life is beyond the reach of physical science; but no sound thinker ascribes to life—that is, to an unknown and mysterious principle — actions that belong to the physical world. So far as a living organism is a chemist, it acts like other chemists; so far as it is a mechanic, it acts like other mechanics; and all processes that are obviously chemical or mechanical will be explainable according to the laws of science, whether they take place in organic structures, or in the laboratory or workshop of man. Natural laws maintain their own course without conflict and without real antagonism. In the highest living being, that which is chemical is as much so as in the earth on which they tread. Qualities and properties beyond chemistry they may possess in abundance, but all the chemical work they do or suffer proceeds exactly in the way which chemical laws prescribe, and without interference from any higher laws which other portions of their nature may obey. When Leonidas defended his country at Thermopylæ, when Socrates emptied the hemlock draught, the divine element in human nature did not change the character of physical processes, and the brain which was animated with their thoughts suffered certain particles of phosphorus to be oxydized, just as might have taken place in a chemist's spoon.

These views have been growing in the most advanced minds for a long time. They were perceived by those who took the grandest views of nature's operations, and traced in all an intellectual unity corresponding with the highest conceptions man can form of the one Ultimate Source of everything that exists. But those who looked only to chemistry, as it existed a few years ago, thought otherwise, and M. Berthelot cites a passage from so distinguished a man as Gerhardt to the effect that "the formation of organic matter depends on the mysterious action of vital force, an action opposed and in constant strife with what we regard as the causes of ordinary chemical action." He added that what the chemist did was opposed to vital action; "he burnt, he destroyed, he worked by analysis; while vital force operated by synthesis, and reconstructed the edifice which chemical force pulled down."

Chemistry in particular, and science in general, is greatly indebted to M. Berthelot for the successful zeal with which he has imitated the so-called "vital force," and reconstructed edifices which analytical chemistry had destroyed. The citation from Gerhardt dates, he tells us, fifteen years back, but "since ten years a great change has taken place; ideas of the constitution of organic matter and of synthesis are profoundly modified; discoveries have been made which have left few chemists who are not preoccupied with questions of synthesis.*" In another passage, M. Berthelot observes that "Synthesis conducts us to the demonstration of this capital truth, that the chemical forces which rule organic matter are really, and without reservation, the same as those which rule mineral matter. This result was reached when it was proved that the last forces gave rise to the same effects as the first, and reproduced the same combinations—a fundamental conception which analysis was able to suggest, but which it was incompetent to prove."†

The microscopist will not be able to appreciate the phenomena of growth and decay which his instrument reveals, if he does not acquaint himself with the elements of organic chemistry. No creature can live and grow unless provided with materials for food and respiration. Plants have their food as well as animals, and their respiration also. The vital changes which occur in animals lead them to give out materials, such as nitrogenous compounds and carbonic acid, which are useful and necessary to plants; while the plant (though by no means exclusively) gives out oxygen, and absorbs carbonic acid.

The oxydation of organic substances is neither more nor less than burning them. We cannot render waste matter innoxious in any better way than by burning it, and this is effected for us under the influence of light and heat by the myriads of minute organisms that take possession of dead matter, and direct the mode of its decay. The microscopic plants are thus essential to the great scheme of things; and objects so small and so simple as the vibrion family, determine changes and produce results which are essential to the existence of man himself upon the globe.

By varying the proportions in which two substances combine, and probably also by varying the pattern in which their atoms are arranged, very different results may be obtained. M. Berthelot observes in the work already cited‡ that "the substances (in the organic world) which only contains two

* Leçons Générales de Synthese en Chimie Organique Professés en 1864, au Collége de France, par M. Berthelot. Paris: Gauthier-Villars. Page 15.

† Page 17.

‡ Page 21.

elements, are in general carbides* of hydrogen. Sometimes they are formed of carbon and hydrogen in equal equivalents, as in the series of carbides which are most important in organic chemistry; at other times, the number of hydrogen equivalents dominates; and in other and more frequent cases, the number of carbon equivalents is most considerable. As examples of these different carbides, I shall cite in the first series olefiant gas, $C^4 H^4$;† in the second group, marsh gas, $C^2 H^4$; in the third, benzine, $C^{12} H^6$; spirits of turpentine, C^{20}, H^{16}, etc., etc.

From this group we pass to compounds of three elements, carbon, hydrogen, and oxygen, which are extremely numerous. They comprehend "the alcohols, fatty bodies, neutral, and acid; acetic acid, essence of bitter almonds, etc., etc. Sometimes the three elements are combined in equal proportions of their equivalents, as in grape sugar, C^{12}, H^{12}, O^{12}, and acetic acid, C^4, H^4, O^4." Most frequently they contain unequal numbers of equivalents, as in oxalic acid, C^4, H^2, O^8; but in general carbon and hydrogen predominate, as in alcohol, ether, stearine, etc.

"Ternary compounds, containing nitrogen, that is to say, bodies composed of carbon, hydrogen, and nitrogen, are much less numerous than the preceding. Among them is aniline,‡ C^{12}, H^7, Az;§ Nicotine, C^{20}, H^{14}, Az^2, etc.

Still more complicated are the quaternary bodies, or bodies formed of four elements. "They are frequently of animal origin. This group contains fibrin, albumen, urea, uric acid, etc. Almost all the vegetable alkalies belong to this group."‖

Besides these we have a limited number of bodies still more complicated by the addition of sulphur or phosphorus, the latter existing in one of the constituents of nerve matter.

A complicated organic substance may be resolved into its elementary constituents by chemical processes that involve its destruction. But by another set of chemical processes, certain elements may be removed, either wholly or partially, and then the compound is changed, but not destroyed. Elements that are thus removed may be replaced by others, and then the compound is changed again, but not destroyed. The principal complicated substances composing or formed by an organic body, may be reduced to certain types, and arranged in series, so that we see how, by changes and transpositions of the sort

* Carbides, formerly called carburets, are compounds of carbon with another substance.

† C. means carbon, H. hydrogen, and the figures give the number of equivalents.

‡ The base of the beautiful dyes so called.

§ Az. means Azote, or nitrogen.

‖ A substance found in opium. Op. cit., page 22.

just mentioned, one may be converted into another. One of the most decided and remarkable animal substances is urea, the chief solid constituent of urine. Those who thought that vital force was alone competent to produce organic bodies, and that it did so by changing the action of chemical forces, are shown to have been in error, through the discovery that, by causing nascent carbonic acid to act upon nascent or free ammonia, urea can be obtained. Many organic compounds can only be formed by bringing certain elements or principles to act upon each other in a *nascent* state. When a gas, for example, is just liberated from a compound, it exhibits an energy of affinity not subsequently displayed. Bodies just liberated are spoken of as being in their *nascent* or new-born state. Any process by which carbonic acid and ammonia can be combined, at the same time that water is separated, gives rise to urea. The formula of urea is C^2, H^4, Az^2, O^2. Thus, as M. Berthelot observes, "it is a neutral carbonate of ammonia, less water.

$$C^2\ O^4,\ 2\ Az,\ H^3\ H^2\ O^2 — 2\ H^2\ O^2 = C^2\ H^4\ Az^2\ O^2."$$

The philosophical conceptions belonging to these questions are more easily apprehended than the details upon which they rest are understood. From what we have already stated, it will be seen that fatty matters and sugars are very similar bodies in chemical composition. Alcohols also are related to them, and all are related to the simple carbides of hydrogen, as, for example, marsh gas or pure coal gas. Marsh gas contains carbon in a very diffused state; but other compounds may be formed by processes which lead to successive condensations of the carbon, and we then obtain benzine, for example, in which the carbon is six times as condensed as in marsh gas, or napthaline, in which its condensation is tenfold.

Olefiant gas is composed of $C^4\ H^4$, and, as M. Berthelot states, "by fixing water on to olefiant gas, we obtain common alcohol, $C^4\ H^6\ O^2$." This is evident from the formula $C^4\ H^4$ (olefiant gas), which becomes $C^4\ H^6\ O^2$ by the simple addition of the elements of water, $H^2\ O^2$.

Again, "if two equivalents of hydrogen are removed (in the form of water) from common alcohol, a substance called Aldehyde is obtained, $C^4\ H^4\ O^2$." By oxydizing aldehyd vinegar is obtained, and this action, which may take place by purely chemical agency in the laboratory, is what the vinegar plant effects as it lives and grows. Organic alkalies are "generally derived by the union of ammonia with divers oxygenized matters, playing the part of alcohols or aldehydes." Another set of bodies, called Amides, "spring from the union of ammonia with acids, or with oxygenated bodies playing the part of acids." In another passage M. Berthelot tells us that "albu-

men, fibrine, osseine, etc., which play so important a part in anatomy and physiology," may probably be considered as amides, though, he adds, their analysis is yet too imperfect to indicate how their synthesis may be effected.*

These considerations will enable us to appreciate an organism, however simple, as a laboratory in which divers substances are brought into contact and juxtaposition, and thus give rise to new compounds, which meet each other in their nascent state, and, by mutual action, cause the formation of other compounds still more complicated. An organism is always something more, and often very much more, than a laboratory, but it is that amongst other things, and in it, as in a laboratory, chemical actions of composition, decomposition, and recomposition occur.

We desire in this article only to present a few elementary considerations not difficult, with due attention, to be understood, and to indicate the very wide and important philosophical conceptions that arise therefrom. Under the microscope many organic changes of growth and decay may be traced. Everything that lives in an animal or vegetable form is changing the matter around it, and being changed in its turn. It lives so long as the sum of such changes build up and preserve its characteristic structure, and, when it perishes under natural conditions, other forms of life determine the way in which it is taken to pieces, and enjoy their being as a consequence of its decay. They moreover prepare the way for a still further and wonderful cycle of life-changes, all tending to a consummation beyond mortal ken.

That which is most wonderful in the proceedings of living beings, considered merely as material objects, is the power which they possess of providing all the circumstances necessary for the complicated actions we have described, and of causing each action to take place exactly at the right time, and with precisely the right force. Here we see that a Presiding Intelligence directs the functions of life.

* An analysis which reduces a compound organic body into its ultimate elements suggests no systematic method for its reconstruction; but such method may be suggested by an analysis which resolves a compound into simpler forms.

CRYSTALS FOR THE MICRO-POLARISCOPE.

BY HARRY NAPIER DRAPER, F.C.S.

THE polariscope is now so usual an adjunct to the microscope, and the beautiful phenomena of which it gives us glimpses are so commonly subjects of intellectual observation, that I feel no apology to be needed as an introduction to a chapter on polariscope crystals. Before, however, I proceed to give a few practical hints and directions to those who may be desirous of making a collection of these interesting objects, I may state that I was first led to experiment in this direction by the following considerations. It occurred to me that the characters which crystalline bodies exhibit when viewed by polarized light might be much more employed as aids to chemical analysis than has yet been shown; that, for example, the very marked difference which distinguishes the alkaloid of the willow and poplar—*salicine*—from that of Peruvian bark—*quinine*—might be found to exist to an equal extent between crystalline inorganic bodies. There are many of these latter which have, like the alkaloids instanced, certain points of resemblance, both as regards colour and crystalline form, and to which therefore it would be advantageous to be able to apply so easy a test. The salts, sulphate of zinc, and sulphate of magnesium, will serve as examples to illustrate what I mean. If these substances, crystallized, as they are ordinarily found in commerce, be placed side by side, the most practised eye will fail to discover any difference which would denote the composition of either. Nor will the microscopical examination of the crystals be of any avail, for the sulphates of zinc and of magnesium form crystals belonging to the same system, and which exactly resemble each other. In a case like this, did it prove that, examined by polarized light, the two salts presented characteristic differences, the Nicol's prisms would give valuable aid. Unfortunately, however, this is not the case, and so far as the micro-polariscope is concerned, a slide of Epsom salt might be labelled sulphate of zinc, or one of sulphate of zinc Epsom salt, without the least chance of the error being discovered.

Although, however, the failure of my attempt to extend the usefulness of this method of observation was signal, the success which attended some experiments, made with the object of devising some method of obtaining constantly good results in these minute crystallizations, was encouraging. This, although to the uninitiated it may appear a very simple matter, is, if the ordinary plan of procedure be adopted, really very

difficult. The usual method is to place upon the centre of the slide a few drops of the solution of the salt which it is desired to obtain in crystals, and either to apply heat until the crystallization begins, or to set the slide aside for spontaneous evaporation. In the first case, although good crystals may frequently be obtained in the centre, the margin is nearly always a confused, almost amorphous mass, which is not only useless as a polariscope object, but very much injures the appearance of the slide. In the second case, the crystals are generally much too large and opaque.

By the adoption of the method which I am about to describe, both these extremes are avoided. The principle is this. The glass being first made chemically clean, it is completely immersed in a hot solution of the salt of which it is desired to mount specimens. On being removed, both surfaces of the slide soon become covered with a fine network of crystals. The whole of one surface, and all but the central portion of the other, being then washed away, a disc of crystalline deposit is obtained, which is perfectly uniform from edge to centre. But few special appliances, and these of the very simplest character, are required, but it is nevertheless well to have them systematically arranged before going to work. The following list comprises all that is necessary—

1. A small Berlin ware evaporating dish, with tripod or other stand for supporting it over a spirit or gas lamp.
2. A stout glass rod about six inches long, having an inch of one end covered with a piece of vulcanized india-rubber tubing.
3. Solution of caustic soda or potash.
4. Distilled water.
5. A small funnel and filtering paper.
6. A pair of horn or wood forceps.
7. The solution of the salt to be crystallized.

The evaporating dish must be of just such dimensions that an ordinary microscopic slide three inches long will rest by its short edges on the sides, so as to be entirely immersed in the liquid contained in the dish. Capsules of this kind are commonly used in chemical operations, and may be readily obtained.

The solution of potash or soda is to be used in removing all trace of grease and organic matter from the glass, and must be strong—in fact, the stronger the better. An ounce of fused potash dissolved in four ounces of water will do capitally. This solution is best kept in a bottle, the mouth of which is covered by a piece of glass, and which is wide enough to admit the india-rubber covered end of the glass rod.

It is not easy to lay down an undeviating rule for the strength of the solutions of the salts themselves. This must be learned by experience, and will be found to require alteration according to circumstances—the degree of solubility of the salt, for example, and the opacity of its crystals. Nevertheless, as some guide, I may mention that in tentative experiments I always begin with a saturated solution—that is, one which contains as much of the salt as water at the ordinary temperature will dissolve. If I find that this gives too thick a layer of crystals, I dilute the solution with water, but it will be found in most cases that considerable latitude can be allowed in this respect without materially affecting the result. The solutions must be filtered just before use, and the access of dust into them or into the capsule carefully prevented.

We will suppose now that we are about to make some slides of chlorate of potash. The best strength for this solution is that which I have just mentioned, viz., one which is saturated at 60° Fahr. The first step in the process is to clean the slide, or rather slides, for a dozen or more may be covered with crystals with the expenditure of but little more trouble than is required for one. Holding the glass slip by its short edges between the finger and thumb, both surfaces are well rubbed over with the india-rubber pad, the latter having been previously dipped into the caustic alkaline solution. When several slides have been thus consecutively treated, the first is held under a stream of water from a tap until the water flows freely over it. If the least appearance of greasiness is perceptible, the treatment with the caustic alkali must be repeated until the glass is perfectly clean. While this part of the operation is being conducted, the solution of chlorate of potash may be filtering into the capsule. This filtration at the last moment is quite a necessary precaution, in order to ensure against the presence of any floating particles of foreign matter. The liquid is next heated to its boiling point, and a clean slide carefully rinsed with distilled water and gently dropped into it; another slide is then rinsed and immersed, and so on until four or five, or even more, have been similarly treated. The lamp is then removed, and each glass slip carefully taken out by its edges with the forceps, and set up on end on a bit of blotting-paper to drain. In the case supposed—that of chlorate of potash—both surfaces of the slides will immediately be covered with a beautifully regular and even layer of small crystals, and if the cleaning process have been carefully conducted, it will be found that either side may be used for mounting. The slides are now—unless the salt employed be liable to alteration by exposure to the air—put away in a grooved box until it is desired to finish them off.

The whole process will be found to occupy scarcely more time than it has taken me to describe it, and a dozen slides may be prepared with as little trouble as is required for a single one by the usual method, and with far greater certainty. It may be objected that, as in this way of operating, quantities of the salts are required which are much greater than are necessary where merely a few drops of a solution are crystallized upon the slide, it could not well be carried out in the case of rare or expensive substances. This, however, is not the case.

Where but a small quantity of the salt is obtainable, results equally good may be had by crystallizing upon the cover glass instead of upon the slide. The cover glasses, which for this purpose should be circular and pretty thick, are cleaned in just the same way as has been described for the slides, and being held by their edges with the forceps are immersed in the hot solution. This modification of the method of operating will, of course, necessitate a corresponding alteration in the process of mounting, which I shall afterwards describe.

Where access can be obtained to a large number of crystalline substances, it is an interesting as well as instructive amusement to ascertain by experiment which of them form good polariscope objects. The following list will, however, be found to include most of the salts worth mounting. In the case of substances which require some departure from the general mode of manipulating which I have recommended, I shall describe that modification of it which is most adapted to each particular crystalline body.

Acid, citric.
„ tartaric.
„ uric.
Ammonium, chloride.
„ oxalate.
„ oxalurate.
Antimony, potassio-tartrate.
Asparagine.
Baryta, nitrate.
Cadmium, sulphate.
Caffein.
Chromium, ammonia oxalate.
„ potassa oxalate.
Copper, acetate.
„ ammonio chloride.
„ sulphate.
„ magnesia sulphate.
Lead, acetate.
Lime, tartrate.
Magnesia, sulphate.
„ platinocyanide.
Mercury, bichloride.
Napthaline.
Narcotine.
Potash, bicarbonate.
„ binoxalate.
„ chlorate.
„ nitrate.
Quinine, iodide.
„ iodo-sulphate.
Salicine.
Santonine.
Sugar of milk.
Thallium, sulphate.
Vanillin.
Zinc, sulphate.

Citric Acid, *Tartaric Acid*, and *Sugar of Milk* may all be crystallized from warm solutions; but as crystals do not at once form, the slides must, after removal from the solutions, be laid aside, protected by a bell-glass for some hours until the viscid, varnish-like layer, with which they are covered, changes from the amorphous to the crystalline form.

Napthaline forms, as I have found, one of the most beautiful objects in the entire range of polariscope crystals. Crystallization from a solution is not, however, successful; it must be sublimed upon the slide. The most simple plan of proceeding is as follows:—Put two or three grains of napthaline in a thin watch glass, and cover it with an inverted pill-box, in the bottom of which a hole, half-an-inch in diameter, has been punched. Place the centre of the slide over this hole, and apply a very gentle heat, by means of a spirit lamp, to the under side of the watch glass. The napthaline is very volatile, and its vapour will condense on the cold slide in very beautiful crystals.

Asparagine is readily soluble in boiling water, and the solution deposits well-formed crystals, which are very pretty objects, but it is by evaporating a solution of asparagine rapidly on the glass, so as to form confused crusts of small irregular crystals, that the most beautiful slides are obtained.

Oxalate of Chromium and Potash may be easily prepared, as has already been described in the INTELLECTUAL OBSERVER,* by dissolving together in hot water one part of bichromate of potash, two parts of binoxalate of potash, and two parts of oxalic acid.

Acetate of Copper crystallizes beautifully from its solution in acetic acid. The ordinary verdigris of the shops is dissolved in this liquid by heat, the solution filtered while still hot and used immediately.

Narcotine and *Santonine* dissolve so slightly in water, that crystals cannot well be obtained from their aqueous solutions. Both are, however, readily soluble in chloroform, forming solutions which give crystals by spontaneous evaporation with great facility.

For *Iodide of Quinine* and *Vanillin* alcohol is the best solvent. Vanillin is the odorous principle of the well-known seed-pod of *Vanilla planifolia*, and its beautiful acicular crystals may be often found completely investing good specimens of the bean. By washing them off with as small a quantity as possible of strong alcohol, a convenient solution will be at once obtained, or the crystals may be brushed directly off—a specimen which has not been spoiled by handling—on to the slide.

Iodo-sulphate of Quinine, more commonly known as *Herapathite*, from the name of its discoverer, forms beautiful

* Vol. i., p. 401.

crystals, which are interesting, not only from their intense polarizing property, but from their formation being an exceedingly delicate test for the presence of quina. The formation of the large tabular crystals of this salt, which are sometimes used as substitutes for tourmaline, requires very nice manipulation and considerable care; but the rosette-like crystals of small size for use as polariscope objects are easily made in the following manner:—

Take Sulphate of Quinine	. .	12 grains.
Acetic Acid	. .	half an ounce.
Proof Spirit	. .	half an ounce.
Tincture of Iodine	. .	25 drops.

The acetic acid is that of commerce, having a specific gravity of 1044 or thereabouts. The tincture of iodine is made by dissolving 40 grains of the metalloid in an ounce of rectified spirit. Dissolve the sulphate of quinine in the acetic acid, and add the proof spirit; then heat to 130° Fahr. and drop in the tincture of iodine. While hot, the liquid thus produced has a dark sherry colour, but on cooling it deposits beautiful spangle-like crystals, which look more like fragments of the wing-cases of cantharides than anything else to which I can compare them. A drop or two of the hot solution allowed to cool upon the slide gives them at once, and the supernatant liquid can be drained off, and the specimen dried under a bell glass. The crystals are best preserved by covering them with a thin layer of a solution of Canada balsam in ether, containing a trace of iodine.

There is perhaps no more really beautiful polariscope object than a well-prepared slide of *salicine;* but none of the books treating on the preparation of objects, with which I am acquainted, give any details as to the method of obtaining those exquisite radiating peacock-feather-like crystals, which one meets with in cabinets, and which are sold by professional mounters. The secret—if secret it be—is this: you take a solution, not too strong, of salicin in water, pour a few drops on a clean slide, and apply a gentle heat so as to evaporate the liquid. If too much heat be used, the salicin will be fused, and perhaps burned; but as the slide becomes dry, the heat must be so managed that the film shall break up into little circular spots, each radiating from its centre. No description will, however, give more than the general method of proceeding in this case; success can only be obtained by experience; and after one or two trials, which will most probably be failures, no difficulty will be found. It is, however, imperative in this, as all other cases, that the slide be chemically clean.

With the exceptions which I have now pointed out, it will be found that all the substances enumerated in the list above

given can be crystallized either upon the slides or upon the circular cover-glasses by immersion in the fluid. This plan has peculiar advantages in some cases. In mounting crystals, for example, as objects for the oxy-hydrogen microscope, I know of no other method by which even surfaces, of sufficiently large size for use with low powers, can be obtained.

I must not omit to mention, that very beautiful flower-like forms may often be obtained by making starting points for the crystallization. This is done by touching the slide with a needle just as crystals begin to appear, at the points from which it is desired that they should proceed. With solution of the double sulphate of copper and magnesia, solution of bichromate of potash with gelatine, and the chloroform solution of santonin, exceedingly pretty fern-like crystals may be thus produced.

Having described the best methods of obtaining polariscope crystals, it now only remains for me to say a few words on the process of mounting. Crystals which are not altered in the air—which are not either deliquescent, efflorescent, or volatile—are best mounted *dry*, as the only fluid which is applicable to the great majority of crystals, namely, *castor-oil*, is not very manageable and has a great tendency to leak from even the most carefully-made cells. For dry mounting, I have found nothing nearly so convenient and so generally applicable as small india-rubber rings. These may be readily obtained of any required size and thickness, but it is best to fix upon one diameter, and keep to the use of that size alone. The cover glasses must be of such diameter that they will, when placed on the rings, reach not quite to their external edges. The best cements are black japan and gilder's gold-size. The former has the advantage, that being quite opaque, it conceals altogether the india-rubber ring.

We will suppose now that we are about to finish off the slide of chlorate of potash, of which I have described the preparation. The first step is to place it upon a Shadbolt turning table, and, with a stiff, mounted needle, describe upon the crystalline surface a circle very little less in diameter than the inside of the caoutchouc ring. Next, with a small piece of wet sponge, clear away all the salt which lies outside the circle, and then carefully dry the slide. Now, replacing it upon the turn-table, make a ring of gold-size all round the crystalline disc, and lay the slide aside until this has become—not dry, but "tacky." Then give one of the surfaces of an india-rubber ring a thin coating of gold-size, and having laid it evenly upon the varnish circle on the slide, press it with another slide until perfect contact is obtained at all points. The cover glass must now be applied, being cemented on with gold-size, and

the whole left until quite hard, when it may be finished off with a coat of black japan. The advantage of the india-rubber ring is, that it effectually prevents the possibility of that most annoying accident—the running in of the varnish to the cell. I have had now for several years crystals mounted in this way which are quite as perfect as when first put up.

In some cases, however, the use of a preservative fluid is imperative. Citric and tartaric acids, and carbonate of soda, for example, will not keep if mounted dry. For these, castor-oil —first recommended, I think, by Mr. Warington—must be used, the india-rubber ring dispensed with, and the cell made in the ordinary manner with cement. But, with castor-oil, neither gold-size or black japan will do for making cells. They must be made of sealing-wax varnish, or, better still, of "diamond cement." The latter is, of course, used hot. Napthaline must also be mounted in fluid, as its volatility is so great that I have never been able to make a cell tight enough to keep it in. Glycerine, however, answers admirably for napthaline. The cell must, in this case, be made and closed with a solution of isinglass in water, as the vapour of either spirit of wine, naphtha, or turpentine, rapidly acts upon the delicate feathery crystals.

Where the crystallization is made upon a cover glass instead of directly upon the slide, the thin disc must be attached to the glass slip with a solution of Canada balsam in chloroform, taking care to avoid air-bubbles, and then mounted with the india-rubber ring and cover glass, as described. In this case no fluid can, of course, be used as a preservative which has a solvent action on Canada balsam.

SUBSTITUTES FOR AN OBSERVATORY.

BY THE REV. N. S. HEINEKEN.

I HAVE been—I daresay in common with many other readers of the INTELLECTUAL—greatly interested in the descriptions of Observatories given by the Rev. E. L. Berthon and Mr. Slack in your pages. To the *casual* observer, however, the comforts of an observatory are generally things only to be hoped for. I am, therefore, induced to forward to you an account of the plan which for several years I have adopted to guard against draughts of air when observing in-doors. When the top sash of the window is let down, I have a square of cloth which I can fix so as to fill up the whole opening. In the centre of this cloth, a circular hole is made about fifteen inches in diameter, in which is sewn what may be called a taper sleeve,

also about fifteen inches long. The narrow end of this sleeve has a band of "elastic" fastened round it; through this the object end of the telescope is passed. Thus a considerable range on every side is obtained, limited only by the size of the central aperture, which, of course, may be still larger. The observer is thus completely shielded from all draughts, and the vision is not so much affected as is usual by the difference in the temperature of the internal and external air. A piece of plate glass fixed in a frame on the tube of the telescope in the line of the finder, around which also the cloth can be brought, enables the observer to direct his instrument. Instead of the plate glass, an aperture may be made in the cloth in such a manner as to allow of its being closed when not in use. As I have adopted this plan with a 5th refractor the object end has always been fairly out of the window and the eye-piece well in. I hope the contrivance may save some of your readers from coughs and colds during their winter observations. I may also perhaps mention, that about thirty years since I employed similar means in lieu of a ball and socket, or rather scioptic ball, for the purpose of sketching the solar spots. Over a hole in a shutter I loosely fixed a square of leather, in its centre an aperture was made, and the object end of a small telescope fastened in it; the looseness of the leather allowed me to turn the telescope in any direction, and a screen fixed at a proper inclination in the room received the paper for the sketch. The back of a swing looking-glass forms a rest for the paper, which can readily be placed at any inclination: a plan somewhat similar to the above was described in your journal of 1862, by the Hon. Mrs. Ward.

Again, to ascertain the correct time is not, generally speaking, an easy matter, and more particularly when one is from home, and consequently without the requisite instruments. By the following simple means, I have arrived at very fair results:—I presume that the traveller will have with him a pocket telescope, and also a telescope clip; he will require in addition a small square piece of board with three levelling screws, a pocket spirit-level, and a parlour candlestick! the bottom of which must be made true by grinding on a flat surface (a door step for instance). If the traveller have a portable telescope-stand, of course he will not need to *borrow* the candlestick! Now having fixed cross hairs on the diaphragm of the telescope with wax, or otherwise, place it in the clip and screw the clip into a piece of wood in the candlestick; level the board *accurately*, place on it the candlestick and telescope, and adjust for observing the contact of the sun's upper and lower limbs with the cross hairs in the morning, leave all untouched till the afternoon, *carefully* then

turn the candlestick on the level board, and observe the afternoon contacts. Apply the ordinary rule for equal altitude observations, and the result will be very near the correct one, even with such an extempore contrivance. The equations to equal altitudes, which are required in the calculation, can, for all ordinary purposes, be reduced in number so as to occupy only a page or two of a pocket-book, entailing only a little extra trouble in working proportions. If the traveller should not happen to have either a levelling board or spirit level, he may roughly supply their places by a thick square of glass (a looking-glass will answer the purpose) and a boy's marble, by which he may adjust it with considerable accuracy. The telescope, in the absence of a clip, can easily be braced to a piece of wood fixed in the candlestick. The candlestick will on many occasions be found to be a most useful telescope-stand, presuming that no better is at hand. This application of it, I believe, originated with Mr. Ronalds, of the Kew Observatory. To the traveller, a substitute for the equatorial, or rather "Smeaton's Block," may also be of service—he may provide one by fixing his portable telescope by its stand on the lid of a box, and raising the lid by a wedge or stay to the angle required for the latitude of the place.

[The success of Mr. Heineken's mode of using a telescope will much depend on the comparative temperature of the room in which it stands, and of the air outside. If one part of the telescope tube is much warmer than the other, air currents will be set in motion, and the distinctness of its performance damaged. The nearer to the eye-piece the "taper sleeve" is fixed, the greater the probability of avoiding this source of error.—Ed.]

HERSCHEL'S CATALOGUE OF NEBULÆ.—THE ACHROMATIC TELESCOPE.—THE PLANETS OF THE MONTH.—OCCULTATIONS.

BY THE REV. T. W. WEBB, A.M., F.R.A.S.

A short notice appeared in our last number of Sir John Herschel's new *General Catalogue of Nebulæ*. From the notes appended to that most valuable monument of laborious accuracy, the following remarks have been compiled, as possessing a considerable degree of interest for every lover of astronomy.

Our readers have already been made aware that a strong impression of variability has existed with regard to some of these mysterious objects. This is by no means dissipated by the observations contained in the present catalogue. It is true

that, in comparison with the full five thousand enumerated, the proportion of suspected nebulæ is not large, and that a great number of such instances may be accounted for, without the supposition of erroneous entries, by their extreme faintness and the uncertainty of our own atmospheric conditions, in addition to the dissimilarity of eyes and instruments. Even in the experience of a single observer, and that one of the highest class, Sir J. Herschel, we are told that "very great differences will occur in the descriptions of one and the same nebula, taken on different nights, and under different atmospheric circumstances, as well as in different states of the mirror and the eye; nor will it at all startle one accustomed to observations of nebulæ to see such an object described at one time as 'faint, small, round,' and at another as 'bright, pretty large, pretty much extended, resolvable.'" It would, indeed, be but natural to dispose of all the recorded variations in this way, but for the tolerably well ascertained fact, or, at least, the strong presumption, that some three or four nebulæ have actually exhibited variations of light; and this marvellous and perplexing disclosure gives wide entrance to any amount of suspicion with regard to the rest; especially when we bear in mind that, from the analogy of variable stars, the rate of change may be extremely diversified, and in many instances exceedingly slow; and that the period during which they have received minute and repeated attention—much less than a century—is comparatively a short one. The existence and the aspect of a little patch of hazy light, so feeble as perhaps to escape any but the more powerful instruments, were of course in the first place facts, and nothing more, and attracted little notice in proportion; it was only when unexpected results began to disclose themselves, that they acquired significance and importance. We have now reached another stage in the inquiry; and since two wholly independent modes of investigation, by direct telescopic examination, and by analyzation of light, seem to converge towards conclusions of the most remarkable nature, every suspicious appearance becomes worthy of notice and record. Changes of three different kinds have previously been suspected among these objects—of *place*, of *form*, and of *brightness*. Those of *place* are very questionable, usually disappearing when more correct determinations of position are obtained: we find, however, three cases in the Catalogue in which such an alteration may be suspected, either in nebulæ or in the stars adjacent to them.* Those of *form* embrace four

* References to position are not given in these cases, because the objects are, generally speaking, too faint for general observation. The possessors of sufficiently powerful instruments should be provided with the Catalogue.

cases—one of a nebula at one time described as round, at another as much extended; two of a seemingly changed direction of position, as though from rotation; and one of a nebula seen round by ♅, much extended by H., and binuclear by Lord Rosse, or as a double nebula joined by faint nebulosity; on which H. remarks, "Is it separating into two, like Biela's comet?" Of variable *light* there are many more instances, about 55 in all, besides the four most satisfactorily established cases—the nebulæ discovered by Hind (2), Tuttle, and Tempel; some of these are mere suspicions, some more strongly supported by evidence. The majority are feeble patches observed by one or both of the Herschels, but subsequently missed, in some instances after repeated observations, by Lord Rosse. The case of 55 *Andromedæ* is a remarkable one. It was eight times examined by the Earl of Rosse without perceiving the haze which induced H. to describe it as "a fine nebulous star with a strong atmosphere, losing itself imperceptibly; diameter 90″;" and which caused even Piazzi with his slender optical means to characterize it as "nebulosa."* The case of 8 *Canum Venaticorum* is somewhat similar. In other instances, nebulæ classed as bright by ♅ have been found very feeble by D'Arrest; in one case the reverse. Besides these, there are six notices of total disappearance, which possibly may have arisen from a comet having been mistaken for a nebula; a coincidence which, perhaps, might have been more frequently expected. On one occasion H. observed a very large diffused nebula distributed in zigzags: Lord Rosse has looked for it seven times in vain.

Having given this brief summary of the evidence in the appended notes, it is important to observe that the inference which would seem to follow from these comparisons, has the full sanction of the illustrious author. "In many instances," he says, "the discordance, or rather contradiction, is so great as to authorize a strong suspicion of variability in the object itself."

Before closing our remarks on the *General Catalogue*, we may find a place for two singular items, unconnected with the general subject, but not undeserving of remark, as illustrations of the law of chances, and the fact that events of extreme improbability will occur from time to time, provided the series is sufficiently extended. In one instance Miss Carolina Herschel, the highly-gifted sister and indefatigable assistant of Herschel I., "rightly brought out the place of the nebula by the wrong star, and wrongly by the right one, and by an odd coincidence the two results agree

* Place of 55 Andromedæ for Jan. 0, 1865.—R. A. 1h. 45m. 14s.—N.P.D. (*i.e.*, North Polar Distance), 49° 56′ 12″.

well, though both wrong." In another, an entry in the Catalogue of Auwers is curious, "for the great number of perfectly accidental errors which have heaped themselves together:" there being a numerical misprint in the synonym of the nebula, in its Right Ascension, and in its Declination! "This is not to be taken as a specimen of M. Auwers's work, which is an admirable example of painstaking devotion, and far beyond any eulogy in my power to offer. But it is a striking instance of the way in which, in the great run of chances, unlucky coincidences will happen."

With regard to the possible movement of nebulæ in space, a highly interesting observation is to be found in an important memoir by the Earl of Rosse, published in the *Philosophical Transactions* for 1861. He there says, "The most remarkable case of suspected change is perhaps H. 1905. Herschel gives a drawing of it, the axes of the two nebulæ in a line. On April 11, 1850, Mr. Johnston Storey remarks the two nebulæ not in a line. April 17, 1855, Mr. Mitchell remarks the two nebulæ are not in a line, but the axes are parallel, and gives a diagram. At the present time they are neither in a line nor parallel, but inclined at an angle of about 16°." A copy is here given of the engraving of these nebulæ in Sir J. Herschel's first Catalogue of 1833. In the *General Catalogue* each is separately numbered 4051 and 4052; but no allusion is made to the Earl of Rosse's observation in the description or the notes. These objects should be carefully watched and drawn at sufficient intervals: they are probably too faint for general observation, but as some of our readers who may possess instruments of adequate light may wish to look for them, the place of the larger (4052), as given in the new Catalogue, is R. A. 15h. 1m. 9s. N. P. D. 69° 56′ 2″ (or D. N. 20° 3′ 58″), consequently a little N. of a line from *Arcturus* through ξ *Boötis*, and rather less than half as far again. They are at the extreme edge of both Nos. 3 and 4 of the star maps of the S. D. U. K., and marked 751 and 752 II.; *i. e.*, of H's second, or faint class of nebulæ.

The Earl of Rosse's memoir, just cited, to which we may have to refer on future occasions, contains abundant proof of a material point, as to which, from his long silence, some doubt had been entertained—the continued and complete efficiency of his magnificent instruments, as well as of their wonderful optical capabilities. He states that for the purpose of bringing out minute stars his 3-foot reflector will occasionally carry a power of more than 2000; and as much, or even more, might

sometimes be borne by the 6-foot. With the latter, he prefers in these observations 1300, given by a lens of ½-inch focus, to a lower magnifier. As to the fittest opportunity for such researches he makes a singular remark, that in winter the finest definition and blackest sky usually occur before 11 o'clock, after which time the sky becomes luminous, and the fainter details of nebulæ disappear: in spring and autumn the change is neither so early nor so decided; but the nights are then shorter. Additional difficulty seems to be thus interposed in the use of instruments of the highest light-grasping quality; nevertheless, the work which they alone can do is too valuable to be relinquished so long as it is at all feasible. And more, it seems, may still be within our reach. The best judge that is, or ever has been, upon this subject, the noble fabricator of the Parsonstown reflectors, expresses himself in this memoir as of opinion that still larger instruments might be made, and would be of service. After all that he has so munificently done, more cannot be expected from him: whether any other wealthy and spirited amateur will attempt a further advance remains to be seen. In France, such endeavours receive encouragement from public sources. At the first general meeting of the recently-formed Paris Association for the advancement of Astronomy and Meteorology, held June 3, 1864, when about 400 members were assembled at the Observatoire Impériale, it was decided that two discs of glass, each 2 feet 5½ inches (English measure) in diameter, should be placed forthwith in an optician's hands, to be formed into an object-glass, and a disc of 4 feet 1½ inch, to be wrought into a silvered speculum: the expense of one of these instruments being defrayed by the Imperial government, and 15,000 francs granted towards the other, if met by a payment of 70,000 francs from the town to which it will be consigned. Our own government at present takes a different view of these matters*; but it must be borne in mind that the number is far greater in England than in France, of individuals whose means would be largely available for the purposes of science; or, possibly (judging from the past), whose taste would direct them into such a channel. Should these undertakings prove successful, Cooke's 25-inch object-glass, now in progress, will no longer be the largest in the world; and though the Earl of Rosse's speculum will still be unrivalled in dimensions, the greater reflective power of silver, and the superior transparency

* The following anecdote of King George III., preserved by Lalande, deserves to be generally known. "Je fus témoin du zèle que le roi d'Angleterre avait pour l'astronomie; il me dit que c'était lui qui avait voulu que Herschel portât son télescope jusqu'à 40 pieds; et comme je lui faisais des remercimens pour les astronomes, il me fit cette réponse édifiante. *Ne vaut-il pas mieux employer son argent à cela qu'à faire tuer des hommes?*"

of the continental air may bring up the performance of its opponent considerably higher than would be expressed by the ordinary proportion of the squares of the linear apertures.

THE ACHROMATIC TELESCOPE.

In our last paper upon the subject, we brought down our notice of this beautiful invention to the completion of its theory, when through the intellectual and manual skill of the elder Dollond, both aberrations, chromatic and spherical, were destroyed by the combination of a concave lens of flint with a convex one of crown (now of plate) glass. In this form they were made for some time with a moderate degree of success. A difficulty, however, in the correction of the spherical aberration, which, though much the smaller in amount, is apt to be the more troublesome, induced the inventor subsequently to divide the convex lens in two, leaving one half in front of the flint lens, and placing the other at the back of it. The reason of this procedure may be easily explained. If a convex lens having a given focal length is replaced by two placed together, whose combined focal length equals it, each of them taken singly will have a focus of twice the length, and the curves belonging to these longer foci will, of course, be much shallower than those of the original single lens. But the spherical aberration diminishes so rapidly with the decreasing depth of curvature that, under favourable circumstances, a division of a convex lens into two producing the same combined focus will reduce the aberration to a quarter of its previous amount; and though this might not be the case in an object-glass where the best form or position for the divided lenses might be inconvenient, yet the reduction would be sufficient to accomplish perfectly the intended object—the bringing of the convex completely under the control of the concave aberration. The additional loss of light from reflection at two more surfaces, and from transmission through a greater thickness of glass—and the crown glass of those days was very green—as well as the additional risk of defective workmanship or centring, did not prevent this triple arrangement from being considered the best possible, and many instruments were constructed of a nominally $3\frac{3}{4}$ inch aperture, that is, of this measure previous to setting, but really reduced by the cell to about $3\frac{7}{10}$ inches, to which a focus of $3\frac{1}{2}$ or 5 feet was given. These bore a very high character: it may be questioned, however, whether their reputation was not in some measure due to the contrast with their predecessors; and there is no doubt that they are surpassed at the present day. More recently opticians, both English and foreign, have reverted to the original double construction, and, as is evident, without any

deterioration in performance.* Dollond's formulæ were not made public; and the attempts which were made in France to imitate his object-glasses mechanically proved, as might be expected, failures; great pains were taken in investigating the theory by the most skilful continental mathematicians, and Clairaut and D'Alembert devised elaborate formulæ; but these had not much success in practice, so that the manufacture was long retained in England by Dollond's successors, and by Tulley, though on what would now be considered a diminutive scale, from the impossibility of getting large discs of homogeneous glass. At length a fresh impulse was given to the manufacture by the celebrated German, Frauenhofer; and the Munich Optical Institute, under his superintendence, long surpassed every similar establishment, till of late years the successful practice of this most delicate species of workmanship has been extended to various parts of the world. The career of Frauenhofer was so remarkable that we pause a moment, in our description, for the purpose of narrating its most interesting facts. This extraordinary man was born in Bavaria, in the year 1787, in a humble condition of life, and being left an orphan, would have been destined to the lathe but for the weakness of his frame. When 14 years of age, while apprenticed to a glass-worker at Munich, he was buried for four hours in the ruins of a house, whence he was extricated under the superintendence of King Maximilian; and to this apparently accidental but really providential occurrence, he was indebted for a patron whose generosity delivered him from a severe master, who denied him the use of books and candle, as well as for a friend, Counsellor Utzschneider, the future partner of his great optical undertaking. Though his education had been so neglected that he was scarcely able to write, he became a diligent student of mathematics, and notwithstanding the pressure of poverty, from which he tried in vain to escape by engraving visiting cards, he devoted much time to grinding and polishing lenses. On the formation of an establishment at Benedictbauern, near Munich, for the fabrication of optical instruments, in which Utzschneider was a partner, the need of good glass became so apparent, that it was determined to manufacture it upon the spot, and for this purpose, the celebrated Louis Guinand was brought from Brenetz, in the Jura Mountains, where he had been very successful in casting flint glass. Skilful workmen were also needed; and after much reluctance in applying, from an impression that Utzschneider had forgotten him, Frauenhofer obtained the post of second optician; this was about the year

* The triple construction is said to have been revived of late in Italy by Amici, from formulæ by Mossotti, with remarkable success.

1807. He now began to distinguish himself. Since lenses, however accurately ground, are very apt to have the truth of their surfaces injured in polishing, he devised a machine, by which the figure is so preserved and corrected to the last, that a perfect result is secured, even in the hands of ordinary workmen; an invention subsequently employed independently by Ross, and at present by his son-in-law, Dallmeyer, in our own country. He reconstructed Guinand's furnaces, and after great trouble and labour succeeded in obtaining glass of purer quality and larger dimensions, as well as in deducing formulæ for determining the most efficient curves. The Optical Institute, which in 1817 had been removed to Munich, was placed under his control, and he continued for a series of years to direct its operations, with latterly 50 workmen under him; and to superintend the construction of object-glasses, such as up to that time the world had never seen, and of which he said that the difficulty of making them equally good with smaller ones was greater than in the proportion of the cube of the aperture. At length his health, which had never been strong, and might, it was thought, have suffered from the intense heat of his furnaces, gave way, and he was cut off by pulmonary disease, at the early age of 40, June 7, 1826, alike respected in private, and distinguished in public life. His most celebrated work was the great Dorpat telescope, 9½ inches in aperture, the prime cost of which was £950; but he was engaged on one of nearly 13 inches at the time of his death. The establishment passed into the hands of Merz, by whom its reputation has been sustained, in part at least, for it is said that the old Frauenhofer achromatic is still considered unrivalled. The extent of its operations is something surprising. It was stated on good authority that three or four years ago Merz had from £25,000 to £30,000 worth of large object-glasses (*i.e.*, from 4½ inches upwards) in stock, besides "heaps" of smaller ones. Of late years, the superiority of Munich work has been questioned by the possessors of English and American telescopes; the material is undoubtedly more liable to decomposition than Chance's glass; and even in point of size they seem to have fallen behind. Frauenhofer was willing to undertake an aperture of 18 inches, but we have not heard of the construction of anything so large. The two largest from that workshop which have attained any celebrity, are those of Poulkova and Harvard College; a third of that size was less successful; one of 16 inches has since been spoken of. But these have been surpassed by Alvan Clark, in America, 18¼ inches; by Porro, in Paris, 21½ inches; and by Buckingham and Cooke, in England, 20 and 25 inches respectively (the latter not yet completed).

In the construction of achromatic object-glasses opticians, however, do not all adopt the same mode of procedure. There is much room for mathematical ingenuity in devising curves, the combination of which is likely to produce good definition in the image, and different proportions are preferred by different artists. The chromatic error is removed very simply in theory by a due proportion between the focal lengths of the two lenses; though in practice it may involve some troublesome adjustment; but the correction of the spherical aberration is a more complicated affair. The problem is what is styled an indeterminate one; that is, it may be equally solved in many ways; and some condition must be fixed upon to limit it: much in the same way as, if it were merely proposed to find two numbers whose sum should amount to ten, there would be five answers equally correct; but if it were required that one of these numbers should be half as large again as the other, it would admit of only one answer, six and four. Different conditions have been assumed by different mathematicians, but not all equally advantageous in practice. Clairaut made the two internal surfaces of equal curvature; but this has no advantage beyond convenience to the workman, and his formulæ do not suit ordinary glass. Frauenhofer corrected the aberration not only for the axis, but as far as possible for lateral rays, so as to produce a very fine field; but in doing this he seems to have sacrificed the accurate union of his external pencils. It is indeed impossible on theoretical grounds to combine the central, the marginal, and the intermediate rays precisely in the same point; but in Frauenhofer's construction the marginal rays were left so much to take care of themselves, that his glasses would not bear a ring-aperture, *i. e.*, having the centre stopped out; and we read of two 11-inch object-glasses, presumably by Merz, which gave no well-defined image when only one-fifth of the surface was left open round the margin. Herschel II. proposed a formula which would render the correction equally perfect for celestial and terrestrial objects; but this would be of but little advantage to astronomers; and the construction is rendered less valuable by the exact correspondence required between theory and workmanship, a correspondence which practical opticians know to be matter of considerable uncertainty. Barlow, therefore, proposed a fresh formula, with the condition that such practical deviations should have the least possible influence upon the result; and this limitation seems the most sensible of all; though whether glasses so ground admit of the high perfection occasionally, and it may be said fortuitously, obtained in the working of other formulæ, is perhaps not certainly known. As old Dr. Kitchener tells us, "in every department of art it

is the same, and the acme of perfection is always accidental, and not to be attained with undeviating certainty by any rules;" but still there are considerations which lead us to think that some rules may be more conducive than others to the attainment of that accidental perfection. After all, the perfection of which we speak is, like all other earthly excellence, only comparative; an inherent peculiarity in the constitution of light, as consisting of successive vibrations incapable of being collected without mutual interference, must for ever bar our advance beyond a certain boundary. Airy has taught us that under the most favourable circumstances "the image of a star will not be a point, but a bright circle, surrounded by a series of bright rings." Only, therefore, so long as the magnifying power is insufficient to render this phenomenon visible, a limit which of course varies with the size of the telescope, can the focal image assume the deceptive appearance of perfection. And this is equally true, whatever construction of instrument, reflecting or refracting, may be employed.

THE PLANETS OF THE MONTH.

MARS is now rapidly leaving us. His diameter, 13″·2 at the beginning of the month, will be only 9″·6 at its close, while in opposition it was 16″·6. During the most favourable position there was fortunately much clear sky, and definition has been more sharp, for the most part, than in 1862; and the evidence is quite satisfactory, both as to the general permanency and occasional variation of the spots.

URANUS may be recognized at present with great ease, from his position about 3° *p* 35 M, the cluster near *Propus*, No. 8 of our list (INTELLECTUAL OBSERVER, Feb. 1864, p. 54); somewhat *s*, however, of its centre. He is still nearer the star *Propus* itself, bearing *np* from it. He may readily be distinguished with a moderate power from the neighbouring stars by his visible diameter (4″·2) and his soft, tranquil, planetary light. I see the minute disc even with 65, but of course better with higher magnifiers.

OCCULTATIONS.

The Moon will pass over several considerable stars during the present month at convenient hours. January 4th, ϵ Piscium, 4 mag., will be concealed from 5h. 53m. till 6h. 59m. —6th. σ Arietis, 6 mag., from 4h. 44m. till 5h. 51m.—8th. B. A. C., 1468, 6 mag., from 5h. 47m. till 6h. 37m.—i Tauri, 5½ mag., from 8h. 45m. till 9h. 24m.—31st. 60 Piscium, 6 mag., from 6h. 1m. to 6h. 52m.

ARCHÆOLOGIA.

During the past month considerable interest has been excited by the accounts of discoveries of early remains of the primeval inhabitants of the extreme northern parts of Scotland. At the meeting of the Ethnological Society, on Tuesday, December 13, Mr. S. Laing exhibited and described the result of his researches among the kitchen-middens of the county of Caithness. The remains thus brought to light consist of shells and bones of fish, bones of animals, human bones, rude implements in stone and bone, a few implements in metal, and a quantity of pottery. The metal implements consisted chiefly of a pair of shears, of the form which is Roman and Anglo-Saxon, and which has been preserved from that time, the spring of which is made of bronze, and the blades have been of steel; and of several large nails, which may be Roman. Of the pottery, the rudest examples are not necessarily older than the Roman period, others are apparently mediæval, and some are comparatively modern, among which is a piece of glazed ware, not older than the sixteenth or seventeenth century. Among the stone implements the most numerous class consisted of whirles for spinning, and other articles, which were considered by Mr. John Evans and others to have been made for no particular object. According to Mr. Laing's account, the people who formed these kitchen-middens proceeded as follows: They inclosed a place for their residence with a circular wall, and, as they sat, they threw all the refuse—shells, bones, broken pottery, etc., and other refuse—on the floor, which thus gradually rose in elevation, perhaps through several generations, though we all know well how rapidly such a "midden" accumulates. It appears that, at distant periods of time, either the same or succeeding occupants got rid of the inconvenience of the old accumulation by forming a new floor upon it, after which, the same process of throwing down the refuse was carried on again. Mr. Laing, who ascribes the origin of these formations to the remote age of the early Stone period, seemed to think that these successive floors marked the arrival of so many new races upon the soil; though it seemed to be the general opinion of the men of science who spoke on this occasion, that there was nothing among the objects exhibited to show a greater antiquity than several centuries after Christ. Professor Huxley, who described the human skulls and other remains at great length, and who thought that they marked the existence in this part of the island of two distinct races of men, did not appear to give them any great antiquity. Of these two races, one was much lower than the other, and he described it as resembling very closely the Australian type.

There was one peculiarity believed to exist in these remains, which is worthy of especial remark. At least one of the bones, the jaw-bone of a child, found in the midden, was damaged in a manner which seemed to show that it had been broken in order to obtain the nerve-pulp or soft substance inside, and this was supposed to show that the people who formed the earlier part of these kitchen-middens were cannibals. This seems to be considered as evidence of an extreme degree of barbarism which can only have existed at a very

remote period. Curiously enough, we have evidence of the existence of cannibalism among the tribes in Scotland at a well-known historical period. In the latter half of the fourth century, the province of Britain, thrown by misgovernment or imperial neglect into frightful confusion, was overrun by predatory invaders, chiefly from Scotland, who ravaged the country in the most ruthless manner. Among those Scottish depredators was a people called the Attacotti, who appear to have been unknown to the Romans before that date, but who are described as the most savage and barbarous tribe with whom they had hitherto come in contact. The well-known ecclesiastical writer, St. Jerome, who flourished at the close of the fourth century (he died in 420), tells us that, in his youth, he had seen some of these Attacotti in Gaul—no doubt, prisoners taken in Britain, and shown, perhaps, as curiosities. He describes them as savages of the lowest character, who were so accustomed to eating human flesh that, when they made raids into districts which abounded in cattle, they preferred the men as diet to the animals; and he informs us particularly of the parts of either sex which they considered as the most delicate for eating—*pastorum nates et fœminarum, et papillas solere abscindere, et has solas ciborum delicias arbitrari.* A writer, of doubtful authenticity, Richard of Cirencester, though the book which has been published under his name seems to have been made up from some materials with which we are not well acquainted, places the Attacotti on the banks of the Clyde (*Clota*), that is, in the maritime districts of Argyll; but the Romans, until a late period of their rule, occupied the Clyde in force, and these Attacotti could hardly have been known there before the fourth century. It is probable, therefore, that the Attacotti were people from the extreme north, who had been gradually drawn southward by the prospect of plunder; and we need go no farther back for cannibalism and any amount of savage barbarism in the county of Caithness.

At the meeting of the Anthropological Society, on the 6th of December, Mr. George S. Roberts laid before the Society the remains found in an early cist, or grave, in the Muckle Heog, on the Island of Unst, one of the Shetland group. The most remarkable of the objects found in this burial-place were seven vessels scooped out of chloritic schist, the largest about seven inches, and the smallest three, in height, which were spoken of rather facetiously as a "prehistoric dinner-service." Vessels of stone are rather of a late than of an early date. We know of no instance of the discovery of such vessels in early interments. The Romans, as we well know, sculptured stone into vessels of the most elaborate forms; but ruder vessels in stone belong especially to the Middle Ages, and are found, not very unfrequently, among monastic ruins. They were developed, in a more finished style of art, into the holy water stoupe and font. Nothing but the form of the interment found by Mr. Roberts in the Isle of Unst, would lead us to consider them as not Christian; while, as Christianity was hardly established in the Shetland Islands before the seventh century, we have no reason for giving any earlier date to this interment; and we know that among the tribes of Western Europe the Pagan forms of burial were kept up long after their conversion to Christianity. At the same time,

these stone vessels are remarkable examples of imitations in that material of earthen pottery.

The excavations at the Jewry Wall at Leicester have been carried very little farther than we announced in our last number, and it is to be regretted that this has arisen from the want of the necessary funds. The three piers at the northern extremity of the wall have been quite exposed to their bases by the removal of the earth, and a low brick wall has been built in front, upon which it is proposed to place an iron palisade, by which the ruin will be protected from mischievous people, and, at the same time, will be perfectly visible to all who feel an interest in it. It is calculated that to complete the excavations, and raise this protecting wall and palisade, will involve altogether an expenditure of about sixty pounds, to which only about thirty has yet been contributed; and surely so small a sum will not be long wanting to complete a work of so much interest. As far as the exploration has yet gone, it appears to confirm the opinion of some of the Leicester antiquaries, that the Jewry Wall was the principal entrance to the Roman city from the west. This wall had two faces, distinctly visible before the buildings now seen at the back of it were raised. That which is now built against and concealed, was the side which was presented in the early history of the place to the approaching visitor. It was the western face of the wall, as that we now see was its eastern face. The western face offered two openings, or entrances, each about nine feet wide, and about twenty feet high from the original level, with an interval of fifteen feet between the two arches. On the eastern side are four arches; but it does not appear that the two at the extreme ends of the structure were ever carried through, the two openings on the eastern side having passed through the two inner arches on the western side, though not in their centres. It has been suggested by Mr. Henry Goddard, a very intelligent antiquary of Leicester, that the two extreme arches on the eastern side served as small guard-rooms or apartments for the sentries on duty.

The remains of a fine and extensive Roman villa have been discovered at the foot of Chedworth Wood, in Gloucestershire. The discovery was made by a gamekeeper, who, while ferreting rabbits, put his hand into one of their holes, and was surprised at drawing out a handful of tesseræ. The site has since been excavated. Eighteen rooms have been found, most of them communicating with a corridor one hundred and twenty feet long. Many Roman imperial coins, and the usual objects found on Roman sites, have been met with; but the most remarkable discovery connected with it is that of two distinct instances of the Christian monogram. The first was the most elaborate, and bore a remarkable resemblance to that found on the coins of Magnentius; the second was less deeply incised, and had the appearance of having been scratched with a pointed instrument. Only one instance was previously known of the appearance of this monogram on a Roman building in Britain.

At a recent meeting of the Archæological Institute, an account was given of excavations made in a building within the ancient entrenchments called the Castle Ring, at Beaudesert, in Stafford-

shire. The building, which was sixty-six feet long and thirty-eight wide, and was divided into two rooms and a kind of lobby, appeared to be mediæval. But the objects met with in the course of digging presented a mixture of mediæval with more ancient, among which flint implements were found. T. W.

PROCEEDINGS OF LEARNED SOCIETIES.

BY W. B. TEGETMEIER.

GEOLOGICAL SOCIETY OF GLASGOW.—*Nov.* 10.

Reptiles of Carboniferous Strata.—Mr. J. Russell exhibited a very interesting set of specimens of the newly discovered Coal Reptiles from the Airdrie blackbands, including the *Anthracosaurus Russelli* of Huxley, and one or two jaws with teeth, not yet described, but with characters, showing them to be true *Labyrinthodonts*. The reptiles now known to have existed in the Carboniferous age, were not poor, small, feebly-developed creatures, but powerful and highly organized. Within a few years the range in time of reptiles has been extended from the Permian downwards, a proof that it is impossible to generalise, on negative evidence, upon the range in time of any class of Vertebrata.

At the same meeting some new species of Chitons from the Carboniferous limestone of the west of Scotland were exhibited.

GEOLOGICAL SOCIETY.—*Nov.* 23.

The Organic Remains in the Laurentian Rocks of Canada.—Sir Charles Lyell, in his inaugural address at the British Association, alluded to the recent discovery of a fossil *Rhizopod* in the lower series of Laurentian Rocks in Canada, which are as old or older than any of the European formations termed Azoic. The occurrence, structure, and the mineralogy of this fossil, now termed the *Eozoön Canadense*, were the subjects of several papers by Sir W. Logan, Dr. Dawson, and Mr. Sterry Hunt, read before the Geological Society, on November 23. The oldest known rocks of North America, composing the Laurentide Mountains in Canada, and the Adirondacks in the State of New York, have been divided into two unconformable groups, which have been called the Upper and Lower Laurentian respectively. In both divisions zones of limestone are known to occur, and three of these zones have been ascertained to belong to the Lower Laurentian. From one of these limestone bands, occurring at the Grand Calumet on the River Ottawa, Mr. J. McCulloch obtained, in 1858, specimens apparently of organic origin, and other specimens have also been obtained from Grenville and Burgess. These specimens consist of alternating layers of calcareous spar, and a magnesian silicate (either serpentine, white pyroxene, pyrallolite, or Loganite)—the latter minerals, instead of replacing the skeleton of the organic form, really filling up the interspaces of the calcareous fossil. Dr. Dawson carefully

examined the laminated material, and he found it to consist of the remains of an organism which grew in large sessile patches, increasing at the surface by the addition of successive layers of chambers separated by calcareous laminæ. Slices examined microscopically showed large irregular chambers with numerous rounded extensions, and bounded by walls of variable thickness, which are studded with septal orifices irregularly disposed; the thicker parts of the walls revealed the existence of bundles of fine branching tubuli. Dr. Dawson, therefore, concludes that this ancient organism, to which he gave the name of *Eozoön Canadense*, was a Foraminifer allied to *Carpenteria* by its habits of growth, but of more complex structure, as indicated by the complicated systems of tubuli; it attained an enormous size, and by the aggregation of individuals, assumed the aspect of a coral reef. Dr. Carpenter corroborated Dr. Dawson's observations on the structure and affinities of *Eozoön*, but stated also that, as he considered the characters furnished by the intimate structure of the shell to be of primary importance, and the plan of growth to have a very subordinate value, he did not hesitate to express his belief in its affinities to *Nummulina*. Mr. Sterry Hunt stated that the mineral silicates, occurring in the chambers, cells, and canals left vacant by the disappearance of the animal matter of the *Eozoön;* and in many cases even in the tubuli, filling up their smallest ramifications, are a white pyroxene, a pale green serpentine and pyrallolite, and a dark-green alumino-magnesian mineral which he referred to Loganite. The calcareous septa in the last case are dolomitic, but in the other instances are composed of nearly pure carbonate of lime. Mr. S. Hunt then gave the results of a chemical analysis of specimens from the different localities, and deduced therefrom the composition and affinities of Loganite; this mineral he considered to be allied to chlorite and to pyrosclerite in composition, but to be distinguished from them by its structure. In conclusion, he showed that the various silicates already mentioned were directly deposited in waters in the midst of which the *Eozoön* was still growing or had only recently perished, and that they penetrated, enclosed, and preserved the structure of the organisms precisely as carbonate of lime might have done; and he cites these and other facts in support of his opinion that these silicated minerals were formed, not by subsequent metamorphism in deeply buried sediments, but by reactions going on at the earth's surface.

December 7.

On the Geology of Otago, New Zealand.—Dr. Hector described the south-western part of the province of Otago as composed of crystalline rocks forming lofty and rugged mountains, intersected by deeply cut valleys, occupied by arms of the sea on the west, and by the great lakes on the east. These crystalline rocks comprise an ancient contorted gneiss, and a newer (probably not very old) series of hornblende-slate, gneiss, quartzite, etc. Eastwards they are succeeded by well bedded sandstones, shales, and porphyritic conglomerates, with greenstone-slates, etc., in patches, all probably of Lower Mesozoic age. Then follow the great auri-

ferous schistose formations, which comprise an Upper, a Middle, and a Lower portion; and upon these occur a series of Tertiary deposits, the lowest of which may, however, possibly be of Upper Mesozoic date, while the upper, consisting of a freshwater and a marine series, are unconformable to it, and are decidedly much more recent. In describing the auriferous formations, Dr. Hector stated that the quartz-veins occurring in the schists were not often true "fissure-reefs" (that is, reefs that cut the strata nearly vertically and have a true back, or wall, independent of the foliation-planes), but are merely concretionary laminæ that conform to the planes of foliation; the gold occurs segregated in the interspaces of this contorted schist, but is rarely found *in situ*. Dr. Hector observed that the period of the eruption of the early Tertiary volcanic rocks must have been one of upheaval, and that the great depth of the valleys, which have been excavated by glacier-action since the close of that period, proves that the elevation of the island, at least in the mountain-region, must once have been enormously greater than it now is.

The Excavation of Lake-basins in the Southern Alps of New Zealand.—Dr. Julius Haast stated that, respecting the formation of lake-basins by the action of ice, he had, quite independently of other writers, come to the same conclusions in New Zealand that Professor Ramsay did in Europe. Referring first to the submergence of New Zealand during the Pliocene period, and to its subsequent elevation, the author stated that the chief physical feature of the country after that elevation was a high mountain-range, from which glaciers of enormous volume descended into the plain below, removing in their course the loose Tertiary strata, and thus widening and enlarging the pre-existing depressions, the occurrence of which had at first determined the course of the glaciers. The author then observes that, the country having acquired a temporary stability, the glaciers became comparatively stationary, and therefore formed moraines, the materials of which were cemented together by the mud deposited from the water issuing from the glacier; new moraine matter would then raise the bed of the outlet and dam up the water below the glacier, and from this moment, he believes, the formation and scooping out of the rock-basin begins; for the ice being pressed downwards, and prevented by the moraine from descending, its force would be expended in excavating a basin in the rock below.

ANTHROPOLOGICAL SOCIETY.—*Dec.* 6.

Prehistoric Remains in Caithness.—Mr. Laing described some very extensive excavations made in shell mounds, near Keiss, eight miles north of Wick, Caithness. These mounds were chiefly of periwinkle and limpet shells, mixed with bones, stone splinters, and bone implements of a rude kind. In two of the mounds there were the remains of buildings, with superposed pavements, showing successive occupations. In the lowest strata of the mounds very rude stone implements alone were found; those in the upper strata were more highly finished, and in one case a pair of shears with bronze blades was found in the superficial layer. These implements were mixed with the shells and bones of animals used for food. Numerous frag-

ments of pottery were discovered, improving in manufacture as they approached the upper strata. The buildings were formed of the sandstone of the district, which splits readily into layers. The bone remains were those of a small cetacean, the ox, horse, red deer, wild boar, and goat. No sheep bones had been found, but those of the dog, fox, cormorant, solan goose, and of the extinct great auk (*Alca impennis*); but the chief food of the inhabitants must have been shell fish. There were no fishing implements, and the bones of fish were rare. Mr. Laing described the opening of a burial place situated near the mounds. This contained several stone coffins, some not more than five feet four inches long, without implements; others six feet and upwards in length; these latter contained, in addition to the skeletons, numerous rude stone implements of the simplest kind. Mr. Laing considered that the remains belonged to the early Stone period, and that the race were part of the primitive population of the country, who had no intercourse with the inhabitants of other districts, where flints or harder stones abounded. The skulls exhibited showed two distinct types—the better developed being similar to the ordinary ancient British skulls, the lower resembling those of the Australians of the present day. These skulls were subsequently described by Professor Huxley at the Ethnological Society. One of them, that of a female, being regarded by him as the most degraded European skull hitherto discovered. In the discussion which ensued after Professor Huxley's remarks, the opinion generally expressed was adverse to the extreme antiquity which Mr. Laing attributed to these remains.

ROYAL GEOGRAPHICAL SOCIETY.—*Nov.* 28.

New Route to British Columbia.—The first paper read was a narrative of an "Expedition across the Rocky Mountains into British Columbia, by the Yellow Head or Leather Pass," by Viscount Milton and Dr. Cheadle. Lord Milton and his companion set forth, in the spring of 1862, with a view to discover a practicable route, through British territory, which should be free from the risks attendant on a road too near the United States boundary. The Leather Pass, which lies in the same latitude as the gold-district of Cariboo, had been formerly used by the *voyageurs* of the Hudson's Bay Company; but the route from this to the settled parts of British Columbia by the head waters of the Thompson River had never yet been trodden by a European. The country between the Red River and the Rocky Mountains is extremely fertile; rich prairies, ready for the plough, being interspersed with woods rich in timber for building and fencing. Coal-beds and ironstone exist in several places. The road beyond Edmonton was merely a pack trail. During three weeks the party progressed slowly over the spongy and boggy soil of the primæval forest, which stretches for 300 miles from Lake St. Ann to the foot of the mountains. They obtained their first view of the range on arriving at the banks of the Athabasca River, which emerges from the heart of the mountains through a narrow gorge, and on reaching the plains expands into a

lake several miles in length. On its western bank is Jasper House, a summer station of the Hudson Bay Company, surrounded by snow-capped mountains. The scenery in the vicinity was described as most enchanting. Three days' march from Jasper House brought them (on the 8th of July, 1863) to the watershed between the Pacific and Atlantic; and on the 10th they struck the Frazer River, which they found, even at this altitude, to be a stream of considerable size, rushing down a narrow rocky gorge. Here the great difficulties of the journey commenced, the only road being along the almost precipitous cliffs of the narrow river valleys. In crossing some of these, the party met with many dangers. They crossed to the valley of the Thompson River, passing one of its sources; and following this for several days they finally came to a point where all traces of path entirely ceased, and an untrodden region of forest and torrent lay before them, which it was necessary to traverse in order to reach Kamloops, where alone they could obtain succour. They struggled through this difficult region for twenty-three days, living on their horses and the small quantity of flour that remained of their stock, and at last arrived, in an emaciated condition, at the Fort of Kamloops, where they were hospitably received by Mr. Mackay. With regard to the practicability of a road being taken across by the route they had come, Lord Milton believed that few engineering difficulties existed of any importance, but it would have to be *made* throughout the entire route between Edmonton and the valley of the Thompson. The great advantages of this line are that it lies far removed from the United States boundary, passes through a country inhabited only by friendly Indians, and forms the most direct communication between Canada and the gold regions of British Columbia.

Mr. Stuart gave a brief account of the fertile regions recently discovered by himself between the centre of Australia and the mouth of the Adelaide River, and which he had explored in his journey across the continent. The climate was healthy, and the land well adapted for European settlers, if Malays and Chinese could be introduced as a labouring class. The Adelaide River had 40 feet of water at a distance of 80 miles from its mouth, and its entrance formed a secure harbour. He proposed calling this region "Alexandra Land."

December 12.

Description of the Malayan Islands of Kalatoa and Puloweh.—These little-known islands were visited by Mr. J. Cameron in the course of a trading expedition, and the result of his visit was the conviction that, although covered with verdure, they contained no fresh water. Kalatoa was uninhabited, but Puloweh, notwithstanding the absence of so great a necessary of life as fresh-water, maintained a population of 5000 souls, a meagre, dingy-skinned race of savages, whose countenances wear a comically good-natured expression. Their ordinary beverage is a liquor made from palm fruits, which is a harmless drink in the morning, but which, from fermenting very speedily, becomes slightly stimulating at midday, and in-

toxicating in the evening. The author affirmed that the daily life of the whole population was a repetition of the various stages of intoxication, corresponding to the process of fermentation of this their only beverage, and that every evening ended in a drunken brawl. The fact of the absence of fresh water in these islands was disputed by Mr. Crawfurd and Mr. Wallace, the latter of whom had visited many similar coral-formed islets in the Malay Archipelago, in which, although no fresh water was apparent on the surface, a plentiful supply could always be obtained by digging through the rich vegetable soil into the coral rock below the level of the sea.

Dr. Hector described the discovery of a practicable route over the mountains from the West to the East Coast of Otago, New Zealand. The author, in the course of his explorations of the west coast, discovered a broad river entering St. Martin's Bay. Its mouth is concealed by a long sand-spit and a deceptive appearance of breakers; so that it is invisible two miles out at sea, but the river is a quarter of a mile in width. There is ten feet of water on the shallowest part of the bar. Four miles inland the stream flows out of a large lake, having a considerable breadth of rich alluvial land on its shores. This river (named Kaduku by the Maories) is capable of forming a good harbour and position for a settlement, and the valley at its head forms a practicable route across the New Zealand Alps to the Eastern side.

NOTES AND MEMORANDA.

CARBONATE OF MAGNESIA AND IRON IN THE METEORITE OF ORGUEIL.—M. Des Cloizeau informs the French Academy that he has discovered a carbonate of magnesia and iron in the Orgueil meteorite. He states that it is the first time this substance has been found in any previous meteorite, and he only obtained four minute crystals in 20 or 25 grammes of the Orgueil specimen. He observes that the presence of a carbonate in the condition of unaltered crystals, shows that the meteorite was not exposed to a high temperature.

THE FLOW OF SOLIDS UNDER PRESSURE.—M. H. Tresca has communicated a paper on this subject to the French Academy, in which he details experiments to show that "solid bodies can, without change of condition, flow (*s'écouler*) after the manner of liquids, if sufficient pressure is exerted upon them." His method consists in operating upon solids composed of separate pieces, the joints of which are known before the experiment begins, and so that their position after the trial indicates the amount and kind of displacement that has been produced. When a block composed of discs (*rondelles*) was placed in a cylinder and exposed to pressure on one of its bases, in some cases amounting to 100,000 kilogrammes, and allowed to flow through a round hole, concentric with the cylinder, it was found that the plane surfaces of the discs were modified so as to form surfaces of revolution in the jet, which were almost cylindrical, descending into it to greater or less distance, and ending in a cap (*calotte*), turning its convexity towards the extremity of the jet. The tubes thus formed were perfectly continuous, and fitted one to each other, so that each line of junction was represented in slices cut at right angles to the axis of the jet. "These lines," says the writer, "show that all the molecules composing the primitive block came individually to take their

place in the jet exactly as the molecules of a running liquid do." M. Tresca thinks that operations of this kind may explain certain geological cases of intrusion of one rock into another.

Thallic Alcohols.—M. Lamy describes in *Comptes Rendus*, No. 19, 1864, three alcohols containing thallium, two being liquids and one solid. Ethyl thallic alcohol, $\left.\begin{matrix} C^4\ H^5 \\ Tl. \end{matrix}\right\} O^2$, has a density exceeding three and a half times that of water, and its refractive and dispersive powers exceed those of bisulphide of carbon. These alcohols are soluble in chloroform and ether; water, or atmospheric moisture, decomposes them quickly. Ethyl thallic alcohol is obtained by placing a considerable mass of absolute alcohol under an air pump in a large flat vessel, and beneath the liquid are leaves of thallium supported by a metallic gauze. A vacuum is made to remove air and moisture, and then oxygen is introduced through tubes containing pumice and sulphuric acid. At a temperature of 20° or 25° C. the thallium is rapidly transformed into a heavy oil that falls to the bottom of the vessel containing the alcohol. A hundred grammes are easily obtained in twenty-four hours, without touching the apparatus. This substance might be useful in spectroscope inquiries.

Eighty-Second Planet.—Dr. R. Luther saw a planet 11 mag. on 27th Nov., A. R. 60° 32′ 11″·3. D + 23° 41′ 20″·1, which he thought was new. His opinion has been verified, and the new planet is named "Alkmene."

Star Eclipsed by Comet I. 1864.—Signor Cacciatore of the Palermo Observatory, states that on the 7th Aug., in the evening, he saw an 8-mag. star eclipsed by the nucleus of the above comet.—*Astron. Nach.*

Dissociation of Carbonic Oxyde.—M. H. St. Claire Deville communicates to the French Academy fresh researches into the phenomena which he terms "dissociations." He observes that "water and carbonic acid, which at the moment of their formation develop a very high temperature, exhibit the apparently paradoxical property of partially reducing themselves into their elements when they are heated to a point considerably below that which determines their total decomposition, or the combination of the simple bodies composing them." In experimenting with carbonic oxyde, M. Deville causes that gas to pass through a highly heated porcelain tube, through the middle of which runs a small thin brass tube traversed by a current of cold water, which keeps it cool, while the walls of the porcelain tube are hot enough to act upon the carbonic oxyde. By this arrangement he partially decomposes the carbonic oxyde. A portion of carbon is deposited in the brass tube, which acts as a refrigerator, and the oxygen set at liberty unites with the rest of the carbonic oxyde, and raises it to the condition of carbonic acid.

Atmospheres of the Earth and Planets.—*Comptes Rendus*, No. 22, 1864, contain a paper by M. Chacornac, *On the Transparency of the Terrestrial Atmosphere and its Reflecting Power*. He states that when observing the transit of Saturn's fourth satellite on 1st May, 1862, with the largest telescope in the Paris Observatory, he obtained proof that the margin of the planet's disc is brighter than the central region, and this seemed contrary to the phenomena presented by Jupiter, whose satellites during transits appear bright spots near the margin, and dark spots when traversing the central regions. This contrast he traces to the difference of reflective power possessed by the two atmospheres. He then details experiments and observations made to ascertain how the terrestrial atmosphere behaved. When the sun is at its greatest height at summer noon, and the sky clear, he found the greatest brilliancy near the horizon. This he states to be noticeable by merely using a screen to shut out the sun and the surrounding aureole. For more accurate observations he employed a small prismatic telescope, the field of which was limited to two small discs separated by a dark space. One of the light spaces was illuminated by rays coming from the zenith, while the other received those from the horizon. "The light from these two regions being partially polarized in directions at right angles to each other, we first ascertained the azimuth under which the two discs presented the greatest difference in illumination, and then bringing its extraordinary ray in contact with the ordinary ray of the least illuminated region, their light was compared in the manner explained in a former

paper." These researches showed that for an equal solar elevation the relative intensities of the two regions varied considerably, even when no distinct clouds appeared, and this variation seemed connected with hygrometric phenomena in the lower regions of the atmosphere. At Paris, Lyons, and in Switzerland, a certain south wind augmented the transparency of the atmosphere, and then the difference between the two regions of the sky at right angles to each other was least considerable, while if a west wind began to blow the relation of the two rapidly converged towards unity. An east wind after rain caused a maximum of difference between the two sky regions, but the persistence of this wind brought back a minimum difference. A sombre mist near Paris and Lyons considerably diminished the reflecting power of the atmosphere near the horizon. On mountain heights, when the zenith and horizon were more than 90° apart, the difference was more striking than on plains. From all his observations M. Chacornac concludes that "the margin of the disc of our planet" must appear to an observer situated outside it in space, "like that of Saturn and Mars, brighter than the central regions, and this indicates that the atmosphere of Jupiter differs from ours, and from theirs, for it appears like the fogs which overhang great cities."

Novel Use of Polarized Light.—In concluding the paper from which the preceding facts are taken, M. Chacornac states that, from the shores of Lake Neuchâtel he watched small cumulus clouds that formed themselves soon after sunset, and found them appear as bright spots seen on a dark ground, or as dark spots on a bright ground, according to whether he shut out the polarized rays, or let them reach his eye. From this it appeared that the proportion of polarized light was sufficiently great, that dark spots became luminous through the action of the *analysing* prism, and thus, passing from the condition of negative to that of positive vision,* could be seen further off. The region of maximum atmospheric polarisation he states to be near the horizon about 78° from the sun, it there amounts to about $\frac{75}{100}$ of the total light which the atmosphere reflects. He suggests that by adding an analysing prism to the eye-piece of a telescope, distant capes at sea, and other objects, might become visible, just as he was able by such means to see alpine summits after they been completely screened from ordinary vision by a light fog.

Action of Aromatic Plants on Silkworms.—M. Ern. Faivre detailed to the French Academy experiments made by placing silkworms on screens pierced with holes and fitted into boxes above a layer of the leaves to be tried. The worms exposed to the action of wormwood were much excited, and they tried to get away. The pulsation of the dorsal vessel was augmented, and their bowels purged. In a few hours death ensued. Fennel produced similar effects on the nervous system and a more marked one on the secretions. Balsam-tansy acted still more powerfully, even killing the sick worms, and causing the healthy ones to emit their silk. Common tansy was less violent. The effects depend upon the quantity of the odoriferous herbs employed, and on the condition of the silkworms. When healthy worms were supplied with mulberry leaves and exposed to the aroma of the vegetables mentioned, they eat their food and made cocoons which were considered of superior quality.

* Negative vision is when a dark object is seen, not by its own light, but by contrast with the light surrounding it. Positive vision is when an object is visible by the light which it emits or reflects.

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